SHAKE

Sensing Hardware Accessory for Kinaesthetic Expression

Model SK6

User Manual Revision J

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Precautions:
Avoid use where there is very high humidity or large amounts of dust.
Avoid use in very hot (over 50 deg C) or very cold (below 0 deg C) locations.
Avoid liquid spillage onto this unit. If this should happen, disconnect the charger immediately. Place in a warm dry location as soon as possible and leave for at least 24 hours.

Warranty:
This unit comes with a 12-month back-to-base warranty on all parts. Firmware updates will be made available on a regular basis and can be downloaded shortly at www.samh-engineering.com

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SK6 Hardware Overview

SHAKE is a tool that provides any computing platform with movement sensing and vibrotactile feedback. Incorporating 6 Degree of freedom inertial sensing[1], compass heading sensing and electric field sensing in a matchbox size enclosure this hardware accessory is a valuable tool for researchers in the areas of human computer interaction (HCI), interfaces for artistic expression and human rehabilitation.

SHAKE will sense linear and rotational movements, absolute orientation / direction and human body proximity and will transfer this information to any computing device such as a mobile phone, PDA or Laptop computer that has Bluetooth™ wireless connectivity. Alternatively, this device can be used in standalone mode where all the sensed information is time-stamped and logged to FLASH memory.

The Bluetooth connectivity allows for up to seven SHAKE's to be connected to one host computer. This provides the possibility to track the movement of multiple limbs or nodes on a person simultaneously.

The internal vibrotactile display is fully programmable and allows haptic sensations to be fed back in response to movement or gestures. For the HCI research domain, this provides the capability of the SHAKE to be used as a sensitive and accurate input device by effectively closing the kinaesthetic loop.

The SK6 is upgradeable. It can accept up to two external sensors connected to the 'Aux' socket (1), and there are two internal expansion slots where additional sensor modules can be installed (for example the SK6-G01 module for 3 DOF rotation sensing).

The SK6 communicates to a host computer using a standard serial port link (using the Bluetooth™ Serial Port Profile or the RS232 standard if using the SK6-USB cable adapter connected to the Aux socket). The data is transferred as ASCII text facilitating integration to the end user's application. This also allows the SK6 to be configured and its output to be viewed using a simple terminal application. Where offline data acquisition is required, the SK6 can also be used in a stand-alone mode – where all the sensor data is logged to the on-board 64Mbit Flash memory.

The typical battery life of the SK6 is about 5 hours when connected to a host over Bluetooth, or 10 hours if connected using the SK6-USB adapter cable or during data logging.

[1] Full 6-DOF inertial sensing required the SK6-G01 Gyro module to be installed

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SK6 Main Features

- Triple axis linear accelerometer with configurable full scale range of either +/2g or +/-6g and a resolution of 1mg
- Triple axis Angular Rate Sensor (Gyro) with full scale range of +/- 500 deg / second and a resolution of 0.1 deg / second[1]
- Triple axis magnetometer with full scale range of +/- 2 Gauss and resolution of 1mGauss
- Two-channel external analog input available over the Aux connector for connecting general-purpose sensors with a 3V 10mA regulated power source available on the same connector.
- Two proximity capacitive sensors on the front of the enclosure that can measure human body proximity to a distance of 10mm
- A three position side navigation switch for general use in the end user's application
- Compass heading algorithm outputs heading information for any orientation of the SK6
- Integrated programmable vibrating motor with braking capability allowing the display of immediate haptic feedback to gestures or other stimuli
- In-built 64Mbit of FLASH memory for data recording / logging
- Accurate Built in real time clock (RTC) for precise time stamping of data samples or events
- Effective resolution on all sensor channels is greater than 12bits
- All sensor channels sampled at 1kHz
- All sensor channels can have the output data rate adjusted between 25Hz and 256Hz with tracking linear-phase or minimum-phase filtering to better than -50dB stopband attenuation.
- Output data rate for all channels can be adjusted between 1Hz and 256Hz with digital filtering disabled
- Two internal expansion slots for add-on modules such as the triple axes angular rate sensor SK6-G01, or external vibration driver module SK6-V01
- Firmware upgradable over the Bluetooth™ radio or using the SK6-USB adapter cable
- Dimensions just 53.6mm *39.7mm * 15.9mm, Weight is 31 grams
- Up to 10 hours operation on a single battery charge

[1] Angular Rate Sensor module (SK6-G01) must be installed for this feature

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SK6 Front, Top and Side Panel

Figure 2 – SK6 Connections

(1) "Aux" or Auxiliary connector. This is a 4-pole 2.5mm socket and is multiplexed between serial communications and external analog inputs. The tip connection always provides a regulated 3V supply with up to 10mA capability.

(2) The "DC 5V" connector takes a Nokia ACP-12X charger for charging the internal battery and for running the SK6 from the mains directly.

(3) The power switch shown here in the OFF position. Slide forward to turn the SK6 to the ON position. This also serves as the reset switch.

(4) The three-way navigation switch. If enabled, the state of this switch is transmitted to the host on any change. This switch is also used as a method to enter the Firmware Upgrade mode.

(5) The position of capacitive proximity sensor number 2. The square indents serve as a tactile indication as to their position

(6) The position of capacitive proximity sensor number 1.

(7) The status LED which indicates the mode of operation, the battery charging status, the connection status amongst other indicators. This LED only provides feedback when the power switch is in the ON position.

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SK6 Getting Started

Included in the SK6 box you should find the following –

- The SHAKE SK6 device
- A UK nokia ACP-12X charger

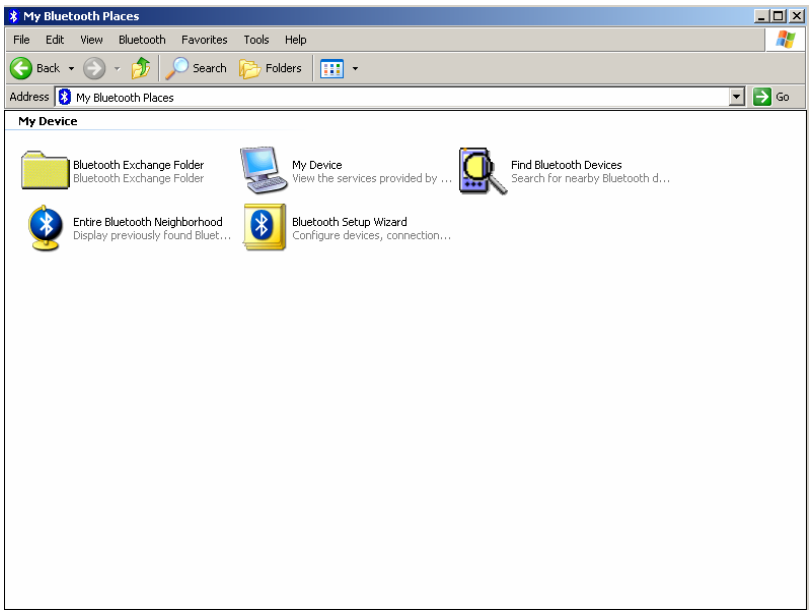
Setting up the SK6 for a connection:

Note: All the references of the form (x) refer to details of Figure 2

Before attempting to connect the SK6 to a computing device, attach the supplied charger to the socket labeled “DC 5V” (2) on the front of the enclosure. Plug the charger into the mains supply and push the SK6 power switch (2) to the position closest to the navigation switch (4) to power the SK6 On. After a couple of seconds the LED (7) will indicate that the SK6 is in standby mode by flashing white / orange or white / green depending on whether the battery is charging (orange) or is fully charged (green). The SK6 is now ready to be connected to a Bluetooth™ master on a host computer. Please see the section “Connection via the SK6-USB cable:” for details on how to initiate a non-wireless connection.

Configuring your computer to connect to the SK6[1] using Bluetooth:

1) Right click on the Bluetooth Icon in the notification area of the taskbar and select “Start The Bluetooth Device” if it is already not started
2) Double click on the Bluetooth Icon in the notification area of the taskbar to open “My Bluetooth Places” in an explorer window, see Figure 3



[1]Note: These directions apply to the MS Windows XP platform only, and with Bluetooth security disabled (default option).

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Figure 3

3) Double click the icon labelled “Bluetooth Setup Wizard” to bring up the “Welcome to the Bluetooth Setup Wizard” Dialog box

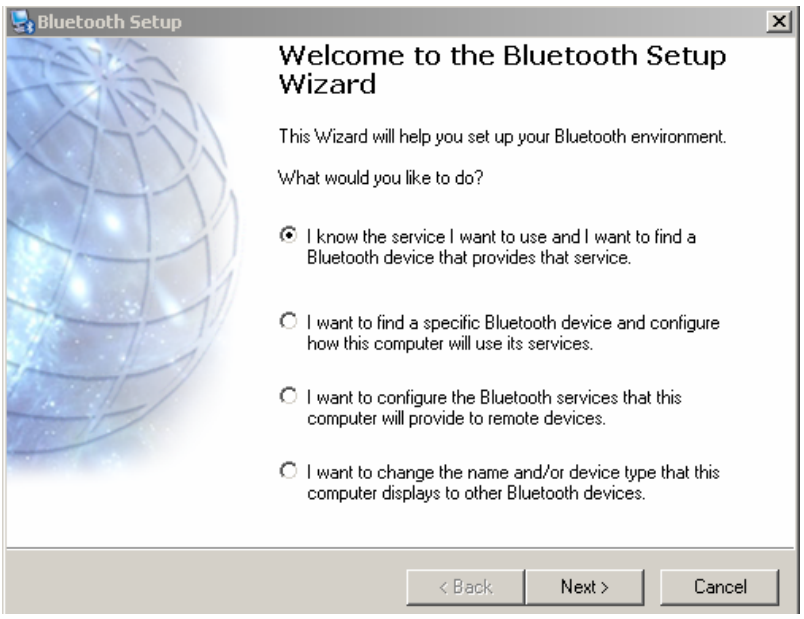
Bluetooth Setup
Welcome to the Bluetooth Setup Wizard
This Wizard will help you set up your Bluetooth environment.
What would you like to do?
I know the service I want to use and I want to find a Bluetooth device that provides that service.
I want to find a specific Bluetooth device and configure how this computer will use its services.
I want to configure the Bluetooth services that this computer will provide to remote devices.
I want to change the name and/or device type that this computer displays to other Bluetooth devices.
< Back
Next >
Cancel

Figure 4

4) Select “I Know the Service I want…” and click the Next button to open up the “Bluetooth Service Selection” dialog box

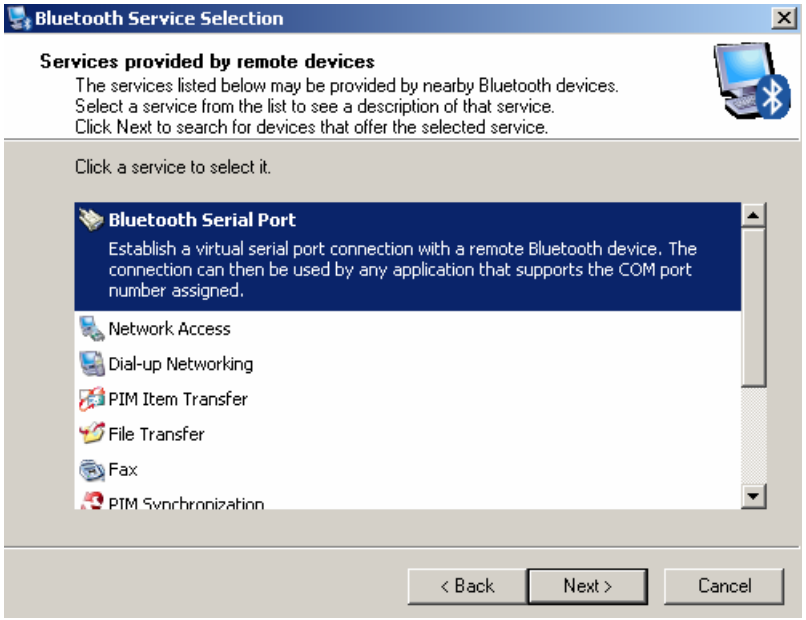
Bluetooth Service Selection
Services provided by remote devices
The services listed below may be provided by nearby Bluetooth devices.
Select a service from the list to see a description of that service.
Click Next to search for devices that offer the selected service.
Click a service to select it.
Bluetooth Serial Port
Establish a virtual serial port connection with a remote Bluetooth device. The connection can then be used by any application that supports the COM port number assigned.
Network Access
Dial-up Networking
PIM Item Transfer
File Transfer
Fax
PIM Synchronization
< Back
Next >
Cancel

Figure 5

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5) Scroll down to the “Bluetooth Serial port” and select it. Press the Next button to open the “Bluetooth Device Selection” dialog box

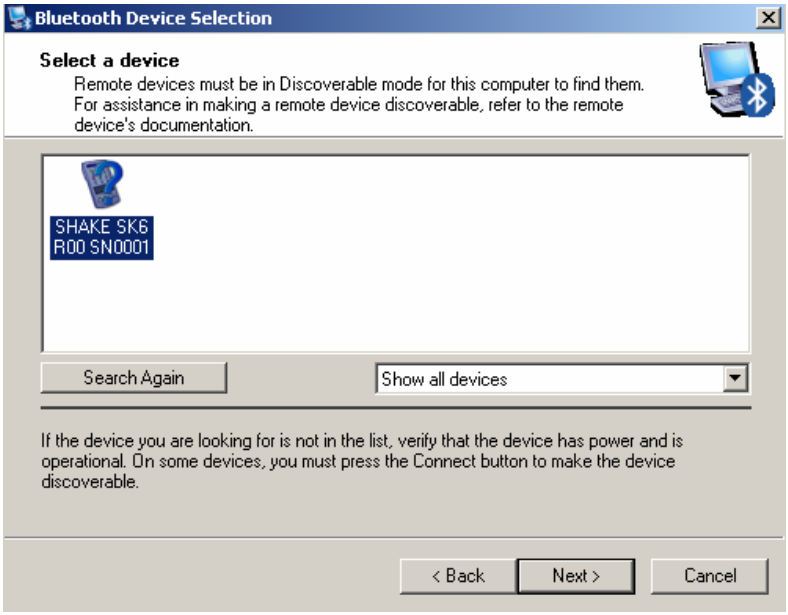
Bluetooth Device Selection
Select a device
Remote devices must be in Discoverable mode for this computer to find them. For assistance in making a remote device discoverable, refer to the remote device's documentation.
SHAKE SK6 R00 SN0001
Search Again
Show all devices
If the device you are looking for is not in the list, verify that the device has power and is operational. On some devices, you must press the Connect button to make the device discoverable.
< Back
Next >
Cancel

Figure 6

6) In the drop down box select “Show All Devices”. Click the “Search Again” button, and the icon for the SHAKE SK6 should appear in the window. Select this icon and press the Next button to open the “Bluetooth Setup Wizard Completion Page” dialog box

Bluetooth Setup Wizard Completion Page
Completing Bluetooth Setup Wizard
SHAKE SK6 R00 SN0001 KC-SPP
A shortcut for this connection with this icon and name will be created on the My Bluetooth Places screen of Windows Explorer. To change the name of this connection, enter the new name in the box above.
Configure
To change the properties of this connection, click Configure.
Start the connection
Create a shortcut and then restart this wizard so that I can create additional shortcuts.
To complete this connection, click Finish.
< Back
Finish
Cancel

Figure 7

7) Click on the “Configure Button” and **uncheck** the “Secure Connection” box **(Important!).**

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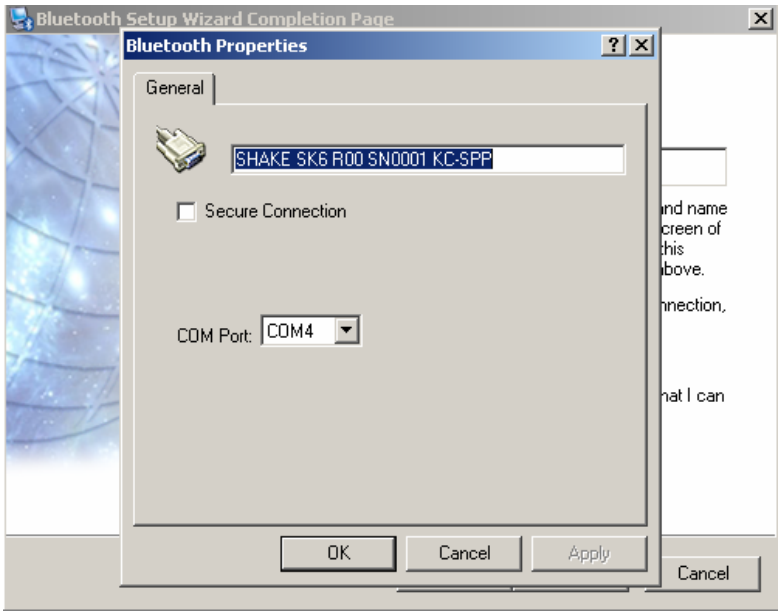

Figure 8

8) Make a note of the COM port that this connection will use from the drop down box and click the “OK” button.

9) Check the “Start the connection” box and click on the “Finish” button.

10) If all has gone to plan, the Serial Port Icon in the “My Bluetooth Places” should indicated that it is connected to the SHAKE SK6, and the SK6 LED should change colour to **Blue.**

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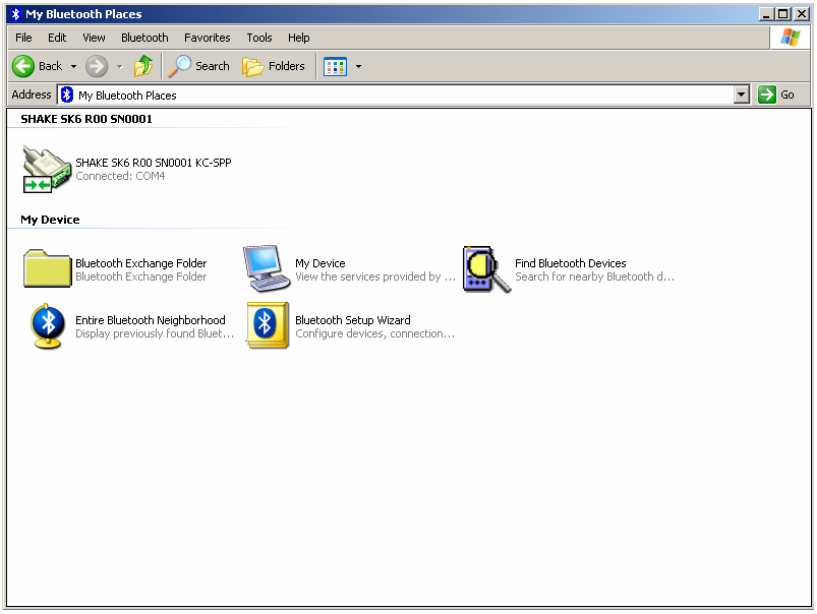

Figure 9

11) To check that the connection is working, go to Start->Run and enter hypertrm.exe followed by return. This will start the native windows terminal application with which you will be able to view the data output from the SK6

12) Enter any name for the connection that is meaningful to you , ie “SHAKE”, and click on the OK button

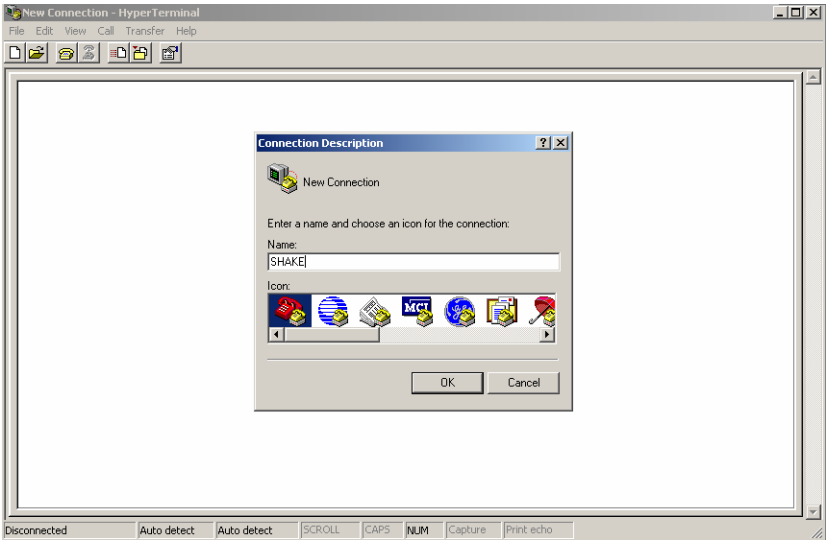

Figure 10

13) Scroll down the COM port number that you noted from step 8 in the “Connect Using” drop down box and click the OK button.

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14) In the “port settings” dialog select 230400 in the “Bits per Second” drop down box see Figure 11

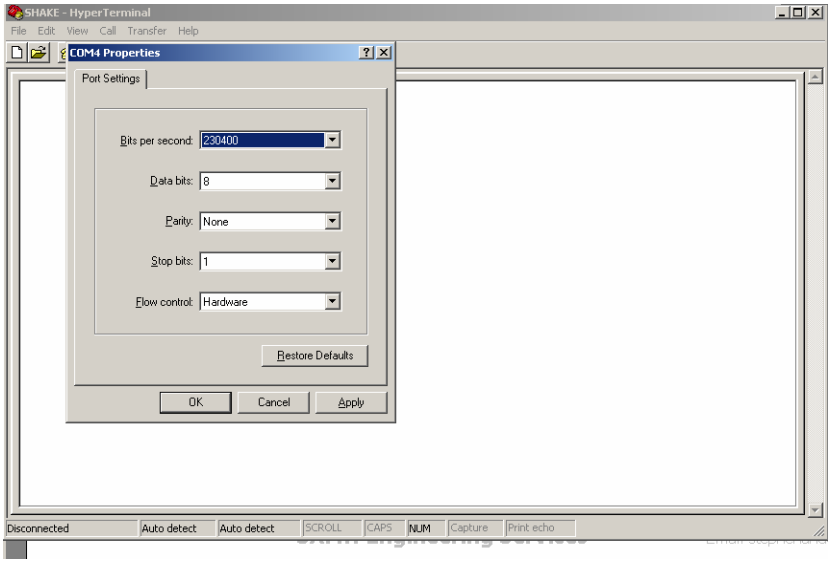

Figure 11

15) Click the OK button. Now the output data from the SK6 should be visible scrolling in the Hyperterminal window (By default the SK6 outputs just the acceleration data packets at a rate of 5 Hertz)

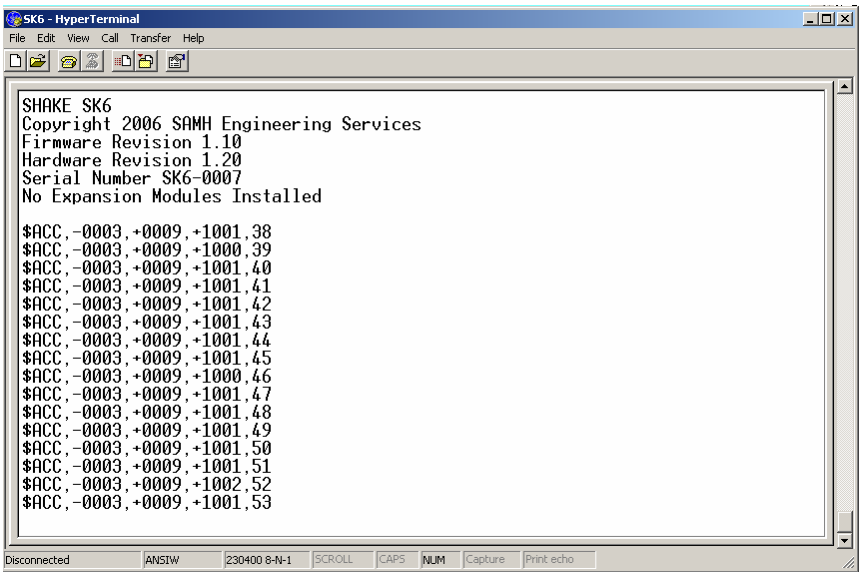

Figure 12

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SK6 Sensors

Overview

The SK6 encompasses a multitude of sensors, each of which is described in detail in later sections. An overview of the intrinsic sensors and their specifications are given in Table 1 below.

	Accelerometer	Angular Rate Sensors[1]	Magnetometer	Capacitive Sensors	Compass Heading	Analog Inputs	Temperature	Navigation Switch
Internal Sample Rate [Hz]	1024	1024	1024	1024	varies	1024	1	100
Number of Channels	3	3	3	2	1	2	1	1
Minimum non-zero Output data rate [Hz]	1	1	1	1	1	1	1	1
Maximum Output Data Rate [Hz]	256	256	256	256	25	256	1	n/a
Positive Output Limit	+6g	+500 d/ sec	+2 Gauss	255	359.9 deg	0V	0degC	n/a
Negative Output limit	-6g	-500d / sec	-2 Gauss	0	0.0 deg	2.75V	60deg C	n/a
Output resolution	1mg	0.1deg / sec	1mGauss	n/a	0.1 deg	1mV	0.25degC	n/a
Output Accuracy	NYD	NYD	NYD	n/a	NYD	<1%	<2degC	n/a
Digital Filtering Available?	Yes	Yes	Yes	Yes	No	Yes	No	No

Table 1 – Specifications of Sensors

[1] Angular Rate Sensor module (SK6-G01) must be installed for this to operate

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Many of the sensors have multiple degrees of freedom, such as the accelerometer and the magnetometer. These sensors output a different channel of data for each of the space dimensions x, y and z. The orientation of these axes relative to the enclosure is diagrammed in Figure 2.

The polarity of the data from the sensors is such that if the entity being measured (such as acceleration) is in the directions of the arrows in Figure 2, then the output will be positive. Otherwise the output will be negative.

The rates at which each of the sensors output data are individually configurable from 1Hz to 256Hz. This output data rate (ORD) is independent of the sampling rate of the sensors, which is currently fixed at 1024Hz. The output data is obtained from the sampled data by use of a multi-rate filter if digital filtering is enabled, or decimated with no filtering if digital filtering is disabled. Please see the section SK6 Digital Filters for further information.

Normally, the SK6 streams data packets at the defined ODR for each sensor, however they can be disabled by modifying the configuration register shown in Table 15. If the packet streaming is disabled for a particular channel, the host can poll for sensor data packets by sending requests as detailed in Table 18. In this scenario, the sensor data is processed at the rate defined in the ODR configuration registers (Table 12), and when a data packet is requested the latest data packet is returned. This may be useful for low duty requirements such as reading the compass heading.

The sensors are factory calibrated, but can be re-calibrated for use in different environments as described in the section SK6 Calibration Modes. The calibration procedures store calibration constants in non-volatile memory and are used to adjust the data from the sensors before being sent as the output data packets. If required, this modification of the data can be individually disabled for each sensor channel to obtain the raw sensor data. Please refer to Table 13 - Data Output Calibration Bypass Register for details.

The three triple axes sensors, namely the accelerometers, gyros and magnetometers are calibrated for cross axes sensitivities in addition to gain and offset. The modification of the output data streams by these cross axes coefficients can be disabled by setting the appropriate bits in the configuration register as detailed in Table 14. Please note that these data modifications will also be disabled if the corresponding bits in Table 13 are set.

Accelerometer

The accelerometer senses the linear acceleration of the SK6. There are three channels of sense data, one for each of X, Y and Z axes as indicated in Figure 2. There are two ranges in which the accelerometer can operate, +/-2g range and +/-6g range (1g is the acceleration due to gravity). The +/-2g range has better accuracy and resolution than the +/- 6g range (better for tilt sensing) .The resolution of the data output is 1mg (one thousandth the acceleration due to gravity). The RMS noise is about 1mg for a 25Hz bandwidth on the X and Y axes, and 2mg of the Z axis. The accelerometers are calibrated for full scale range and zero acceleration offset at the factory, but they can be re-calibrated at any time by the end user by running the calibration process on the SK6. See the Accelerometer Calibration section for more details.

If the acceleration sensing is not required, it can be powered down and save about 0.6mA of current drain.

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Gyro / Angular Rate Sensor[1] (option)

The angular rate sensors (aka Gyros) measure angular rate movement of the SK6. This sensor complements the accelerometers to provide a full six degree of freedom inertial sensing capability. This may be used for capturing complex gestures.

There are 3 channels of sense data, one for each of Pitch (rotation about the Y axis), Roll (rotation about the X axis) and Yaw (rotation about the Z axis). Please refer to Figure 2 for the directionality of the rotation sensing. The measurement range is +/- 500 degrees of rotation per second and the output resolution is 0.1 degree / second. As with the accelerometers, they are calibrated at the factory but only for the SK6 that they are calibrated in. If the module is taken from it's parent SK6 and inserted into another SK6, re-calibration may be required. Calibration is also possible by the end user if they have access to a quartz-locked direct drive vinyl turntable such as the Technics™ 1200 turntable. See the SK6 Calibration Modes section for more details.

The Pitch and Roll channels for the SK6-G01 Gyro module are particularly sensitive to the temperature of the SK6. During the factory calibration, this temperature sensitivity is calculated and stored in the block of calibration constants. By default the gyro outputs are compensated for this temperature dependant offset but this can be disabled by modifying the configuration register described in Table 16. However the thermistor that measures the internal temperature of the SK6 is a few mili-meters away from the gyros so the temperature compensation will not be accurate immediately after the gyros have been powered up. If accurate offset is required, it is recommended to allow the gyros to settle for about 3 minutes prior to using the data.

If the angular rate sensor is not required, it can be powered down and save about 15mA of current drain.

Magnetometer

The magnetometer senses the magnetic field strength in the immediate vicinity of the SK6. There are three channels of sense data, one for each of X, Y and Z axes as indicated in Figure 2. The maximum sense range for these sensors will vary from unit to unit, but a minimum range of +/- 2 Gauss is guaranteed. The output data resolution is 1 mGauss. The magnetometers are calibrated for full scale range and zero magnetic field strength offset at the factory, but they can be re-calibrated at any time by the end user by running the calibration process on the SK6. See the Magnetometer Calibration section for more details.

If the magnetometer is not required, it can be powered down and save about 4mA of current drain.

Note:
The magnetometer is best used when operating the SK6 from the internal battery. The charging currents from the charger can influence the output by several milli-Gauss, especially the Z axis. Future revisions of the firmware may compensate for this.

Capacitive Sensors

The capacitive sensors comprise of small metal plates directly under the top surface of the SK6 as indicated in Figure 2 (6) and (5). Their output takes two distinct and individually configurable forms.

[1] Angular Rate Sensor module (SK6-G01) must be installed for this to operate

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The first of these takes the form of a steady stream of data (with range 0 to 255) depending on the proximity of another part of the human body to the plates (such as a fingertip). The proximity range is about 0 to 10mm, with the value increasing exponentially with the inverse of the proximity.

The second output form is as discrete events, with dedicated data packets attributed to these events. For each of the two sensors, there are two triggers – when the proximity value rises above a programmable threshold and when the proximity value falls below another programmable threshold. These thresholds can be configured by modifying the appropriate registers that are listed in Table 17. It is important to keep the rising trigger level above the falling trigger level or unpredictable behaviour may result. Typical values that would work for the rising and falling threshold levels are 200 and 150 respectively. Note, that output of these data packets is disabled by default – to enable them set bit #4 of the configuration register listed in Table 8.

This discrete trigger form of the capacitive sensor's output can also trigger any of the internally programmed vibration profiles. This provides the possibility to add low latency haptic feedback in response to actuation of the sensors. The vibration profile for each trigger can be set by modifying the configuration registers listed in Table 17, and they can be enabled by setting the appropriate bits listed in Table 8.

The capacitive sensors are calibrated for a typical usage scenario at the factory, but they can be re-calibrated at any time by the end user by running the calibration process on the SK6 (See the Capacitive Sensors Calibration section for more details). When calibrated, the streaming output value should read 0 when nothing is in close proximity to the sensor pads, and 255 (0xFF) when the pads are firmly touched.

Note: For optimum operation, the SK6 should be held in one hand such that the back is flush to the end user's hand.

Compass Heading Sensor

This is not a distinct sensor in itself, but rather an algorithm that uses data from the magnetometer and accelerometer to calculate the compass heading. The heading is always relative to the earth's magnetic north pole, so it is up to the end user to compensate for their location on the planet to obtain the heading to true north.

The heading reading is tilt compensated, so the heading will read true regardless of the orientation of the SK6 (with a traditional mechanical compass, it is paramount to the accuracy that it is kept absolutely normal to the gravity vector). The heading given will always be in the direction of the long axis of the SHAKE, labelled the x axis in Figure 2.

The output is in represented in tenths of one degree, i.e. the range is from 0 to 3600. The accelerometer and magnetometer data is always filtered using the MP digital filter number 1 (see Table 3). If the digital filter enable bit is set for the compass as in Table 11, then the heading computation output is averaged over 4 computations. This may be useful if a steadier heading is required, at the expense of update speed.

Please note that for the compass to operate accurately it is paramount that the accelerometer and magnetometer be calibrated. See the SK6 Calibration Modes section for more details.

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External Analog Inputs

The SK6 hosts the ability to connect up to two external analog sensors via the Aux connector (1). The connection details can be found in the section SK6 External Analog Inputs. These channels are sampled at 1kHz, and have an analog cut-off point of about 160Hz. The output has a resolution of 1mV, and the measurement range is 0V to 2.75V. These inputs are over voltage and reverse voltage protected to +/- 8V. The Aux connector also hosts a 3V power supply connection so that resistive type sensors can be connected without the need for an external supply or battery.

Note: If using the SK6-USB adapter cable to connect to the SK6 the analog inputs will be unavailable since the Aux connector is shared. Under these circumstances, no output data packets will be streamed for the analog input channels.

Temperature Sensor

The SK6 contains an internal thermistor that measures the temperature of the main circuit board. Typically this temperature will rise by about 4 deg C above the surrounding ambient temperature after about 30 mins of use although this depends on several factors such as the SK6's processor load and any extra insulation surrounding the SK6's enclosure. This thermistor is also used for temperature compensation of the Gyro module zero rate offset, if the SK6-G01 is installed.

The output range of the temperature sensor is from 0 degC to 60 degC, and the resolution is 0.25 degC. The temperature is sampled once per second and is not available as an auto output like the other sensor channels – it must be requested by the host by sending the Temperature Request packet.

This sensor is factory calibrated at 25 degC, but they can be re-calibrated at any time by the end user by running the calibration process on the SK6. See the Temperature Calibration section for more details.

Navigation Switch

On the right hand side of the SK6 is a three position navigation switch (4). If this is enabled, any press of this switch will result in one of 4 data packets being sent to the host. The rate at which this switch is sampled is 100 Hz, so the maximum latency is about 10mS (if connected via the SK6-USB adapter cable, otherwise the Bluetooth latency must be added to this figure). The 4 packets represent any of the following: the switch being moved to the up position, down position, centre position and released to the off position. This switch may be useful to trigger the start of a gesture capture, or as part of a gaming controller.

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SK6 Operation Modes

The operation of the SK6 is best described by breaking it down into three modes of operation. Each of these modes is described in the following paragraphs.

Standby Mode

Standby mode is the default mode that the SK6 reverts to once the power switch (2) is moved to the ON position and the navigation switch (4) is not activated. In this mode, the LED (7) will flash white with a period of 1 second and all of the sensors and the vibration driver are powered down. The SK6 will wait in this mode until another device initiates a Bluetooth connection at which point the SK6 will transition to Run Mode.

Run Mode

If a master Bluetooth device successfully connected to the SK6 in Standby Mode or if the navigation switch (4) was held in the down position while the power switch (2) is moved to the ON position, the SK6 will transition to Run Mode.

Once in run mode, the LED (7) will illuminate **blue.** The following text will be immediately output:

```
SHAKE SK6
Copyright 2006 SAMH Engineering Services
Firmware Revision A.bb
Hardware Revision C.dd
Serial Number SK6-xxxx
No option module detected in Slot 0
No option module detected in Slot 1
```

Where

A	represents the firmware revision major number
bb	represents the firmware revision minor number
C	represents the hardware revision major number
dd	represents the hardware revision minor number
xxxx	represents the serial number formatted as a 4 digit decimal number

note: The start-up display splash can be requested at any time when connected, see Table 19

This is the main mode of operation for the SK6. The sensors that are configured to run will be powered up, and if data streaming is enabled the data from these sensors will be streamed over the serial link at their configured data rates.

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The SK6 will process a wide range of commands from the host such as configuration commands, vibration driver commands, data logging commands and calibration mode commands.

The SK6 will remain in run mode until either

1) the serial link is disrupted
2) the host initiates a disconnect*

At which point the SK6 will revert back to Standby Mode.

If the SK6 is running on the battery and the battery becomes empty, then it will enter Sleep Mode.

*note: If the SK6 data logging is recording at the time the host initiates a disconnect, then the SK6 will remain in Run Mode and the LED will turn a blue-green (aqua) color

Sleep Mode

If the battery reaches a critically low level, the SK6 will automatically shutdown to a low power sleep mode. The LED (7) will flash at a low duty cycle the colour **red** when the battery is critically low, and will extinguish once in sleep mode. To revert to standby mode, the mains must be reconnected to start re-charging the battery and the power switch must then be cycled to reset the SK6.

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SK6 Data Connections

The SK6 can accept data connections from either

1) a master Bluetooth device using the serial port profile
2) an emulated serial COM port via the SK6-USB cable adapter

In both cases, the connection will appear to the application of the host computer as a standard serial (COM) port. The settings for the COM port are –

BAUD = 230400

Parity = no

Stop bits = 1

Start bits = 1

Software flow control = off

If low latency and high data through-put are paramount, consider using the SK6-USB cable connection. When properly configured, this will allow latencies of below 2mS, whereas with the Bluetooth connection, the latencies could be as high as 50mS.

Connection via Bluetooth:

When the SK6 is in Standby Mode, the SK6 will listen for connection requests from another Bluetooth master device, and accept any incoming connection. All security features of the Bluetooth protocol are disabled by default so no pin code will be required. Once a master device has connected, the SK6 will enter Run Mode. An example of how to connect to the SK6 by this method from a windows PC is outlined in the SK6 Getting Started section.

Note: The default Bluetooth device name is “SHAKE SK6 R00 SNxxxx”
where xxxx represents the unique device serial number in a 4 digit decimal format.

Bluetooth Security:

If security is required it can be enabled by setting the appropriate bit as detailed in Table 8. The PIN number will be the last 4 digits of the Bluetooth address of the SHAKE (with digits a to f all lower case) - this can usually be found easily with the host software / interface. Once the Bluetooth security has been changed, the SHAKE must be power cycled for the changes to take effect.

Connection via the SK6-USB cable:

If the navigation switch (4) was held in the down position while the power switch (2) is moved to the ON position, the SK6 will boot up straight into Run Mode, communications over Bluetooth will be disabled and communications will be enabled using the SK6-USB adapter cable (via the Aux connector (1)).

Note: The SK6-USB adapter cable uses the FT232RQ chip manufactured by the Future Technology Devices International Ltd. Drivers are available at
http://www.ftdichip.com/Drivers/VCP.htm for the following operating systems

• Windows 98, 98SE, ME, 2000, Server 2003, XP

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- Windows Vista / Longhorn
- Windows XP 64-bit
- Windows XP Embedded
- Windows CE.NET 4.2 & 5.0
- MAC OS 8 / 9, OS-X
- Linux 2.4 and greater

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SK6 LED Visual Feedback

The SK6 contains a single RGB Light Emitting Diode (LED) (7) to provide the end user with feedback as to the state of the device. Table 2 summarises the LED feedback.

The LED colour / brightness can also be overridden by updating any of the volatile configuration registers as detailed in Table 29 - LED colour override registers. There are three registers, one for each of the red, green and blue components of the LED. If any of the registers are set to a value that is not equal to zero, the override is enabled and the colour is displayed according to the value in the registers. The colour will remain the same until either the registers values are adjusted, or the SHAKE is power cycled. In the latter case the SHAKE reverts to normal state-based visual feedback.

LED Constant	LED Flash Fast[6]	LED Flash Slow[7]	Indicates that:
Red	None	None	Firmware Upgrade over Bluetooth
Orange	none	None	Firmware Upgrade over Serial Cable
Blue	none	None	Run Mode, Battery operated
Blue	none	Orange	Run Mode, Mains Operated, Battery Charging
Blue	none	Green	Run Mode, Mains Operated, Battery Full
Blue	none	Red	Run Mode, Mains Operated, Battery Empty
Blue	Red[8]	any	Run Mode Data packets are being lost due to bad connection or too high data rate
none	White	Orange	Standby Mode, Mains Operated, Battery Charging
none	White	Green	Standby Mode, Mains Operated, Battery Full
none	White	Red	Standby Mode, Mains Operated, Battery Empty
Blue	White	any	Run Mode, Data Logging Recording
Aqua	White	any	Standby Mode, Data Logging Recording

Table 2 – LED Visual Feedback

[6] The “LED Flash Fast” is illuminated for 0.5seconds and extinguished for 0.5 seconds repeatedly
[7] The “LED Flash Slow” is illuminated for 0.5 seconds and extinguished for 1.5 seconds repeatedly
[8] This will appear as a flicker with no apparent periodic pattern. Combined with blue, it may appear as purple

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SK6 Digital Filters

The SK6 has a low pass filter slot available for each sensor channel. These filters are individually configurable for stop band frequency and phase characteristics (Linear and minimum phase options are available). There are a total of 9 different filter stop band frequencies to choose from, and as such this limits the output data rates (ODRs) to a fixed set of values if the filter is enabled for the given channel. At present, the lowest frequency that the filters operate to is about 12Hz, which corresponds to an ODR of 25Hz.

If an output data rate (ODR) of below 25Hz is selected via the configuration registers then filter number 1 is engaged and the data that is output is decimated from filter 1's output with no additional filtering. This means that data can be lost. If the ODR is selected equal to or above 25Hz, then the actual ODR from the SK6 is set to the equal or next highest ODR as listed in Table 3. This time no data is lost, however the ODR is limited to the set of 9 values as listed in Table 3.

If ODRs other than those listed are required, then the filter must be disabled, and hence run the risk of aliasing the data.

In order to avoid temporal smearing of the signal the linear phase filter option should be chosen. This may be especially useful for gesture recognition on the accelerometer and angular rate channels.

If latency is of higher importance, then choose the minimum phase filter option for the required channel. This type of filter minimizes the group delay of the filter at the expense of a non-linear phase response.

Filter Number	1	2	3	4	5	6	7	8	9
Configuration Output Data Rate [Hz]	25	35	49	68	102	128	171	205	256
Actual Output Data Rate [Hz]	25	35.3	48.8	68.3	102.4	128	170.7	204.8	256
Stopband Frequency [Hz]	12	18	24	34	51	64	85	102	128
Stopband Attenuation [dB]	-50	-50	-50	-50	-50	-50	-50	-50	-50
Passband Ripple [dB]	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
-3dB Cut-off for LP type [Hz]	5.6	11.4	16.5	24.4	38.5	50.6	70.8	86.6	105.6
-3dB Cut-off for MP type [Hz]	6	12.5	17.6	25.9	40.8	52.9	72.9	88.7	108.9

Table 3 - Digital Filter Specifications

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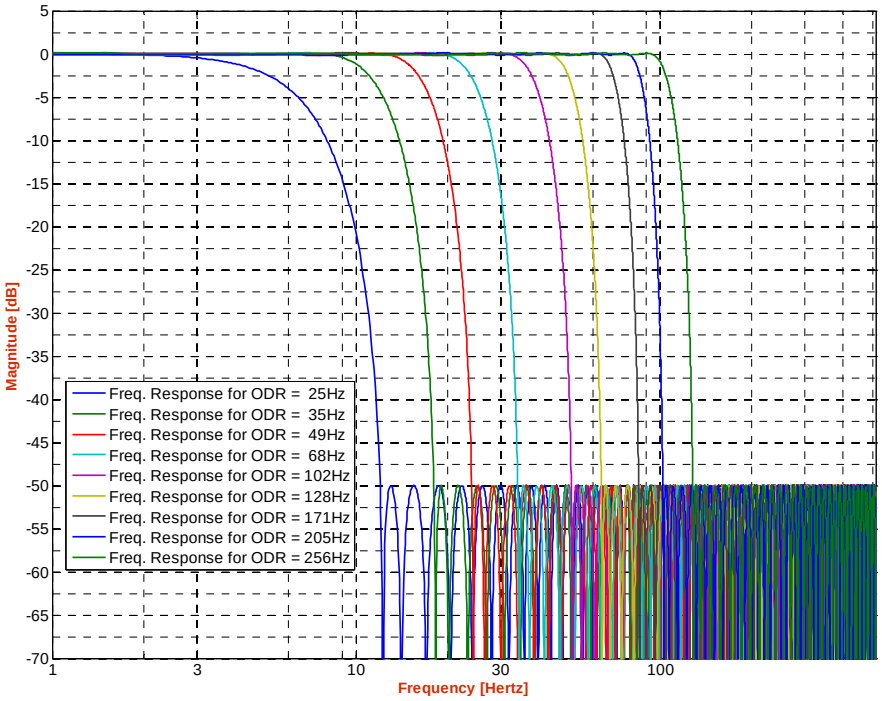
Magnitude [dB]
Frequency [Hertz]
Freq. Response for ODR = 25Hz
Freq. Response for ODR = 35Hz
Freq. Response for ODR = 49Hz
Freq. Response for ODR = 68Hz
Freq. Response for ODR = 102Hz
Freq. Response for ODR = 128Hz
Freq. Response for ODR = 171Hz
Freq. Response for ODR = 205Hz
Freq. Response for ODR = 256Hz

Figure 13 - SK6 Linear Phase Digital Filter Magnitude Responses

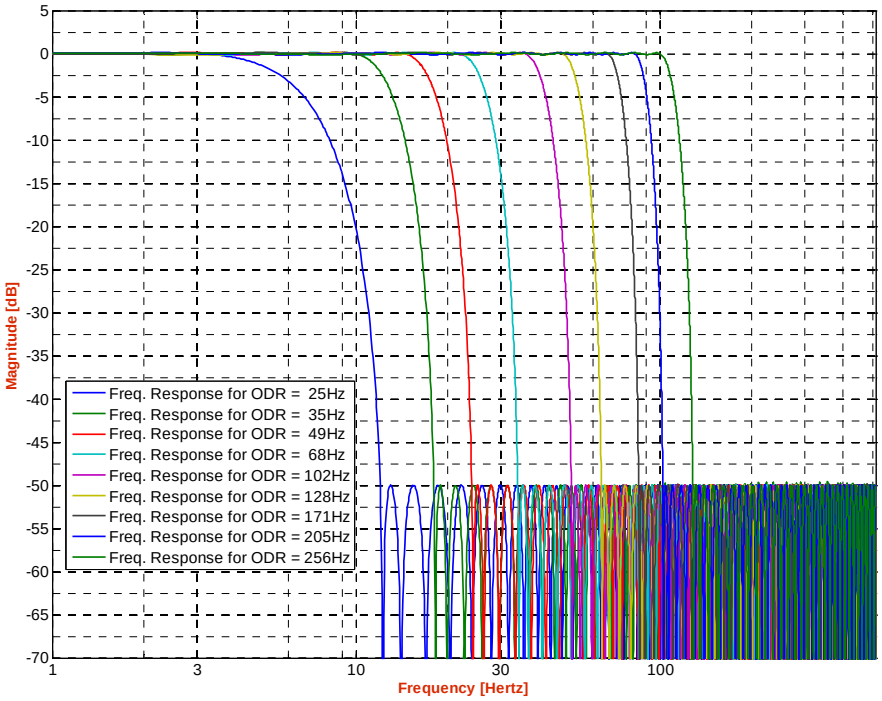
Magnitude [dB]
Frequency [Hertz]
Freq. Response for ODR = 25Hz
Freq. Response for ODR = 35Hz
Freq. Response for ODR = 49Hz
Freq. Response for ODR = 68Hz
Freq. Response for ODR = 102Hz
Freq. Response for ODR = 128Hz
Freq. Response for ODR = 171Hz
Freq. Response for ODR = 205Hz
Freq. Response for ODR = 256Hz

Figure 14 - SK6 Minimum Phase Digital Filter Magnitude Responses

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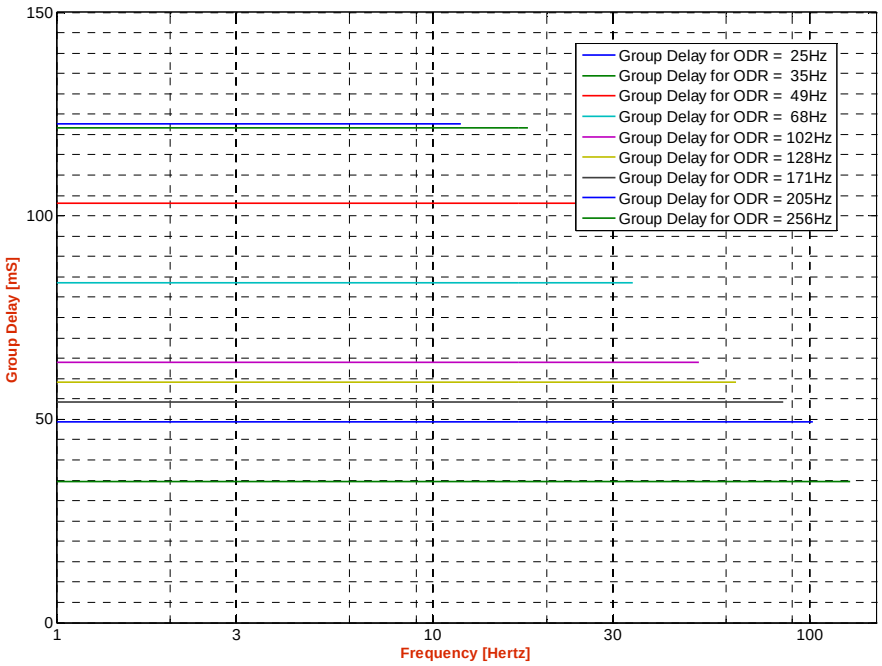

Figure 15 - SK6 Linear Phase Digital Filter Group Delay

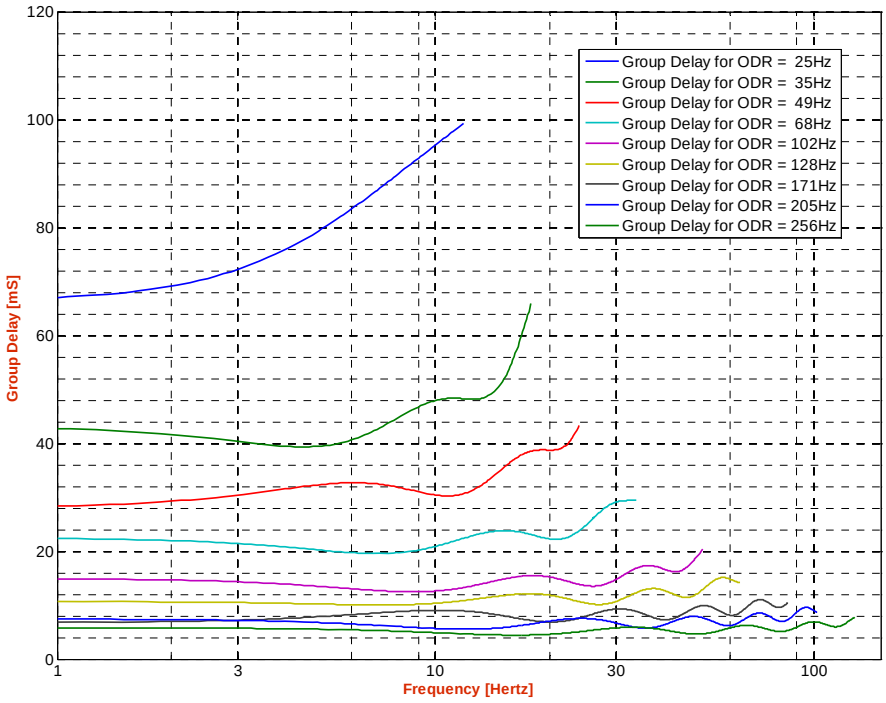

Figure 16 - SK6 Minimum Phase Digital Filter Group Delay

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SK6 Vibrotactile Display

The SK6 has an onboard vibration motor with variable speed control and active braking. Vibration profiles can be programmed and triggered by the host (see the section Vibration Request Registers for details on how to trigger the vibration profiles).

The vibration profiles consist of a series of events that indicate the motor speed and the time in steps of 10 milliseconds for which that speed will be applied to the motor. Every profile can have up to 32 of these events and there can be up to 255 different profiles.

To upload a vibration profile to the SK6 use this packet format –

$VIB,addr,res1,res2,res3,speed1,end1,speed2,end2 …..,speedN,endN~

Where *addr* is a fixed width two digit hex number from 1 to 255 (01 to FF) representing the address of the location that the profile is to be written to. Address space 00 is reserved and cannot be written to.

res1,res2 and *res3* are fixed width 2 digit hex fields that are reserved for future use and should all be set to 00

speed1 is a fixed width 2 hex field representing the initial speed that the motor is to run. If this field is set to 00, then the motor brake will be applied. Set this field to FF for maximum speed.

end1 is a fixed width 2 digit hex number representing the end time of the *speed1* value and the time at which the Speed2 value will be applied to the motor. A value of zero will cause the playback to cease and subsequent elements in the profile will be ignored. Each unit represents 10mS of time so the range is from 10mili seconds to 2.55 seconds

The last character must be a ~, this indicates to the SK6 that the end of the packet has been reached.

Example:

To upload a vibration profile to address space number 10 (0x0A) that drives the motor full speed for the first 200mS, at half speed for the next 200mS and then applies the brake you would send the following packet –

```
$VIB,0A,00,00,00,FF,14,7F,14,00,00~
```

The SK6 will respond with (if checksum is disabled) -

```
$ACK,VIB ,00[CR][LF]
```

if successful or

```
$NAK,VIB ,00[CR][LF]
```

if unsuccessful

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SK6 Battery and Power Supply

The SK6 contains an internal lithium-polymer battery and an on-board charging and supervisory circuit. The SK6 should only be connected to the supplied Nokia ACP-12X charger to avoid damage to the SK6. The battery will charge once the charger is plugged into the mains and connected to the DC-5V power socket (2). Typically it will take 2.5 hours to fully charge. It will charge regardless of the position of the power switch (2), though the LED indicator (7) will only illuminate to provide charging feedback when the switch is in the ON position.

The battery has a capacity of 330mAHr, and the average current consumption of the SK6 when connected via Bluetooth is 60mA (with the Gyros disabled). Thus the typical battery life is about 5.5 hours. If the unit is being used without Bluetooth either by using a serial cable for data communications or logging data to FLASH memory, the battery life can be up to 10 hours. Further improvements in battery life can be achieved by powering down sensors that are not required (see the section Power Control Configuration Register #1)

The battery charge level can be queried any time the SK6 is connected to the host. The level is a value with the range 0 to 255, where 0 indicates that the battery is empty, and 255 that the battery is fully charged. See the section Battery Level Register for details.

The status of the charge circuit can also be queried by the host. The SK6 will reveal whether the external power supply is connected, whether the battery is charging and when the battery is fully charged. See the section Power Status Register for details.

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SK6 Data Logging

Data Logging Overview:

There may be circumstances where the SHAKE is required to acquire data while not tethered to a host computer. To facilitate this requirement the SK6 can be instructed to capture any set of sensor's data and record it to non-volatile FLASH memory. This recorded data can subsequently be uploaded at any time to a host computer for offline processing / analysis.

Data Logging Operation:

The data logging RECORD function stores data that is normally streamed over the serial link to non-volatile memory. All settings that apply to the sensor data such as the output data rates, filter cut-off frequencies, calibration parameters etc. are also applied to logged data. However, to allow for low power consumption, the data streams can be disabled from being transmitted over the serial link without affecting the data logging (see Table 15).

A rudimentary form of data compression is applied to the sensor data before being written to memory. This compression algorithm stores only differences in the data from one sample to the next. These differences are stored in variable sized blocks from 3 bits to 16 bits depending on the magnitude of the difference. Thus the number of data samples that can fit in the 60MBits of memory will depend on the nature of the data. For slowly varying data, the capacity can be over 3 times the capacity than that for rapidly varying data.

To save further memory space a timestamp packet is only written to memory each time recording is re-started. On data playback the time stamp is reconstructed from the initial timestamp packet and the knowledge of the sample rate at which the data was logged at. The timestamp will precede every packet of data when the PLAY command is invoked. As an example, an entire accelerometer packet on playback would take the form –

```
$TIM,0000627549,$ACC,-0001,+0015,+1007
```

Where the time stamp number is a 10 digit decimal numeral (this example indicates a timestamp of 627.549 seconds).

All event packets such as those from the navigation switch and capacitive sensor triggers are also logged. On playback, such an event would take the form

```
$TIM,0000785628,$NVD
```

This example shows a navigation switch down event at time 785.628 seconds

Data Logging Control:

Data logging is controlled by commands that behave like the transport controls of a tape recorder. All of these commands can be sent by writing to the configuration register that is detailed in Table 22

The RECORD command will start logging from the current position in memory.

The PAUSE command will pause recording and playback while retaining the current r/w position in memory.

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The STOP command will stop recording and playback and rewind the r/w position to the beginning of memory.

The PLAY command will stream all the contents of the memory over the serial link, starting at the current r/w position of memory.

The TIMER_RESET command zeroes the data logging timestamp clock and should be sent prior to recording. The host can keep a record of the time at which this reset was applied facilitating it to reconstruct the timestamps to UTC values later.

Once the RECORD command is invoked and the data logging recording is in progress, it is not possible to modify any of the configuration registers. Any attempts to do so will be met by a $NAK (Not-Acknowledge) response. This prevents any changes (such as adjusting the output data rates of the sensors) to be incurred while recording is in progress. If changes are required during a record session, then the PAUSE command may be invoked, the necessary changes made to the configuration registers, and the RECORD command may be sent to re-invoke recording. The timestamp clock continues to run as normal while the recording is in PAUSE mode.

Data Logging Status:

The status of data logging can be read at any time. The state of the data logging transport can be ascertained this way (such as whether data logging is recording, playing or stopped) by reading the register detailed in Table 26.

There is also a pair of registers that contain a count of the total number of data packets written to memory, where each count of these registers represents 100 packets, see Table 28.

In addition, there is a single byte register that indicates the proportion of space left in the memory bank, where 255 would indicate that the memory is empty, and 0 would indicate that the memory is full, see Table 27.

Also, the text "Logging Data Upload Complete." is output once all the packets stored in memory have been played back.

Data Logging Record Termination:

The data logging record function will continue indefinitely until either one of the following situations is reached-

1) A STOP or PAUSE command is issued.
2) The memory becomes full.
3) The battery reaches a critically low level.

In the event that power is lost to the SK6 during recording (i.e. if the battery runs flat) the data that is recorded up to this point will be available to play back once power is restored. The data retention of the FLASH memory is typically 20 years.

Data logging memory capacity:

Due to the nature of the data compression, the capacity of the data log memory will vary depending on the data that is being recorded. Table 4 gives the maximum and minimum number of packets that can be stored for both types of packets (Triple axis packets and Single axis packets).

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Packet Type:	Min Packets:	Max Packets:	Average Packets:
Triple Axis	1,071,400	3,750,000	2,410,700
Single Axis	2,500,000	3,750,000	3,125,000

Table 4 – Data Logging Packet Storage Capacity

The total time that the data logging can run for can be estimated by dividing the average storage capacity of packets by the output data rate for that sensor. For example, if the accelerometer were set to record at a data rate of 100Hz with all other sensors disabled, then the total time that recording will run is approximately –

Estimated Record Time = 2410700 / 100 [seconds] = 24107 seconds = 6.7 hours

Setting up the SHAKE for data logging:

To set up the SK6 for data logging, please follow these steps-

1) Configure the logging sample rate for each sensor channel by setting the output data rate (ODR) parameters detailed in Table 12
2) If required, configure the digital filtering for each sample channel by setting the parameters detailed in Table 11
3) If the output data is not required in real-time while logging is in operation a lot of power can be saved by disabling data streaming. This can be achieved by modifying the configuration register detailed in Table 15
4) Send the command to stop data logging (see Table 22) – this resets the write location back to the beginning of the memory block
5) If absolute timestamps are required, send the command to reset the logging timestamp clock (see Table 22), and if required, make a note in your application of the time that the reset was invoked. This will allow reconstruction of the absolute timestamps in the host application upon playback of the logged data.
6) Send the command to start data logging recording (see Table 22). LED feedback that recording is in progress is provided by a **white** flash superimposed over the constant **blue**.
7) If required, disconnect the communications to the SK6 while recording to increase battery life (either by disconnecting the Bluetooth link or removing the SK6_USB cable). While the Bluetooth serial link is disconnected, the LED background color will change from **blue** to **aqua**.
8) The status of the data logging recording can be observed by connecting the serial link and reading the registers detailed in Table 26, Table 27 and Table 28
9) When desired, data logging recording can be terminated by sending the STOP command, see Table 22
10) The recorded data can now be uploaded to the host by sending the PLAY command, see Table 22. This process could take a long time if there was a lot of data recorded so it is advisable to connect the power supply during this process. To estimate the amount of time that this process will take, read the number of packets in memory that need to be played back, (by reading the registers detailed in Table 28)

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SK6 Communication Protocol

Communication overview

The data from the various sensors in SHAKE are periodically output over the serial connection by default. Parameters such as the output data rate and the filter type can be configured as required. Alternatively, automatic data output can be disabled for any set of sensors by setting associated the output data rate parameter to zero, and data can be requested by the host on a sample by sample basis.

There are numerous parameters that can be adjusted within the SHAKE device. These parameters are stored in a non-volatile memory block. Access to this memory block is available to the host computer using either a 'Read' or a 'Write' command.

There are three types of packets –

(1) Data Packets

(2) Command Packets

(3) Acknowledge / Response Packets

All the packets that are sent out by the SK6 can optionally contain a two byte checksum field. Since the Bluetooth Serial Port Profile has inbuilt error correction, this should not be required if connecting wirelessly. However, if connecting using the serial cable, it is recommended that this field is enabled.

The SK6 Data Packets

Data packets are those packets that are output by the SHAKE device to the host application, typically they encapsulate the SHAKE's sensor data. These packets default to ASCII format so that they can be easily viewed in a terminal type application and parsed with higher level host applications. If high data throughput or minimum processor overhead on the host are required (such as on a mobile phone or PDA where processor resources are limited) then raw output data mode can be selected. This mode outputs the data in a packed format and typically consumes one fifth of the bandwidth required by ASCII mode. This format will look unintelligible when viewed with an ASCII viewer or on a terminal application and care should be taken when parsing it to get meaningful results.

ASCII Data Packets Skeleton Structure

The default data packets take on a format that is very similar to that used by the NMEA protocol (common is GPS devices). This should allow the partial re-use of source code already developed for NMEA.

All packets are in ASCII making debugging easier. The data will display clearly and in a human readable format when displayed in a terminal type application.

The packets take the following format if the checksum is enabled:

*$packetID,data1,data2,dataN*CS[CR][LF]*

The packets take the following format if the checksum is disabled:

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$packetID,data1,data2,dataN[CR][LF]

Where packetID is a three character field unique to the packet type.

data1 are the data fields, comma separated. The number of data fields varies depending on the packet type.

CS is the checksum field (optional). It is a two character hexadecimal string representing an 8 bit modulo 256 checksum value of the entire packet up to and including the dataN field.

[CR] is the ASCII character for 'Carriage Return', and has a value of 0x0D ('\r' in C or C++)

[LF] is the ASCII character for 'Line Feed', and has a value of 0x0A ('\n' in C or C++)

The timestamp field is common to all the data packets and is incremented every output sample. It is a decimal value of two digits. The value wraps to 0 on incrementing from 99. This field provides a method to check for missing samples in the host computer's application software.

Accelerometer Packet

`$ACC,sdddd,sdddd,sdddd,dd*CS[CR][LF]`

The data fields are X, Y, Z and Timestamp respectively.

The X, Y and Z data fields are in decimal format and fixed to 4 significant digits, and is preceded by a sign character (ASCII '+' or '-'). Each count represents a milli-g (one thousandth of the acceleration due to gravity), thus the field can represent accelerations between -9.999g and +9.999g. For the SK6, the actual range of the accelerometer is limited to about -6.000g to + 6.000g

Total packet length = 30 bytes with the checksum enabled, 27 bytes otherwise.

Angular Rate Packet[9]

`$ARS,sdddd,sdddd,sdddd,dd*CS[CR][LF]`

The data fields are Pitch, Roll, Yaw and Timestamp respectively.

The X, Y and Z data fields are in decimal format and fixed to 4 significant digits, and are preceded by a sign character (ASCII '+' or '-'). Each count represents a deci-degree/second. (one tenth of an angular degree of rotation per second), thus the field can represent angular rates between -999.9deg/second and +999.9deg/second (however the hardware will limit the values to approx +/- 600 deg / sec with +/- 500 deg / sec guaranteed))

Total packet length = 30 bytes with the checksum enabled, 27 bytes otherwise.

Magnetometer Packet

`$MAG,sdddd,sdddd,sdddd,dd*CS[CR][LF]`

The data fields are X, Y, Z and Timestamp respectively.

[9] Angular Rate Sensor module (SK6-G01) must be installed for this to operate

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The X, Y and Z data fields are in decimal format and fixed to 4 significant digits, and is preceded by a sign character (ASCII '+' or '-'). Each count represents a milli-Gauss, thus the field can represent magnetic flux density between -9.999 Gauss and +9.999 Gauss. The SK6 guarantees a range of at least +/- 2 Gauss.

Total packet length = 30 bytes with the checksum enabled, 27 bytes otherwise.

Compass Heading Packet

```
$HED,dddd,dd*CS[CR][LF]
```

The data fields are Compass Heading and Timestamp respectively.

The compass-heading field is in decimal format and fixed to 4 significant digits. This value is unsigned and each count represents one tenth of a degree of rotation. The valid range is from 0000 to 3599.

Total packet length = 17 bytes with the checksum enabled, 14 bytes otherwise.

Capacitive Sensors Packet

```
$CS0,dddd,dd*CS[CR][LF]
$CS1,dddd,dd*CS[CR][LF]
```

The data fields are Steady State proximity and Timestamp respectively.

The proximity value is a relative value in the range 0 to 255 that follows the proximity of a user's hand to the sensor. The closer one's proximity to the sense plates the higher the value output.

Total packet length = 17 bytes with the checksum enabled, 14 bytes otherwise.

External Analog Inputs Packet

```
$AI0,dddd,dd*CS[CR][LF]
$AI1,dddd,dd*CS[CR][LF]
```

Where the data fields are analog voltage in mV and Timestamp.

There are two analog inputs AI0 and AI1, and there is a dedicated output packet for each.

The external analog inputs are sampled with a full scale range of 2.5V and one output least significant bit represents one mV. Thus the valid output range is from 0 to approx. 2800.

Total packet length = 17 bytes with the checksum enabled, 14 bytes otherwise.

Navigation Switch activation packets

```
$NVU[CR][LF]
$NVD[CR][LF]
$NVC[CR][LF]
$NVN[CR][LF]
```

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These packets are sent out within 10mS of a press or release of the three position navigation switch (4).

NVU == Navigation switch pressed to the up position (in the direction away from the power switch (2))

NVD == Navigation switch pressed to the down position (in the direction towards the power switch (2))

NVC == Navigation switch pressed in the centre position

NVN == Navigation switch has been released to its normal position

Total packet length = 6 bytes

Capacitive Sensors Threshold Packets

```
$CU0[CR][LF]
$CL0[CR][LF]
$CU1[CR][LF]
$CL1[CR][LF]
```

If enabled, these packets are sent out within 5mS of the capacitive sensor proximity values crossing the thresholds as listed in Table 17

CU0 == Capacitive Sensor **#0** proximity value has crossed the **upper** threshold

CL0 == Capacitive Sensor **#0** proximity value has crossed the **lower** threshold

CU1 == Capacitive Sensor **#1** proximity value has crossed the **upper** threshold

CL1 == Capacitive Sensor **#1** proximity value has crossed the **lower** threshold

Total packet length = 6 bytes

The SK6 Command Packets

The command packets are those that are issued by the host application to the SHAKE device. They consist of two types, a Read command and a Write command. These commands take two arguments, the address to read/write to/from and the 8-bit value to write in the case of the write command. In the case of either a Read or Write command the read or written value of the requested address is returned in an Acknowledge/Response packet.

Configuration of the many parameters of the SHAKE device is achieved by writing the appropriate values to the appropriate registers using the Write command. Details of the registers and the parameters they represent can be found in the section

For the event packets, the number output will be as follows –

0x0001 = Navigation Switch released
0x0002 = Navigation Switch pressed UP
0x0003 = Navigation Switch pressed DOWN
0x0004 = Navigation Switch pressed CENTRE

0x0005 = Capacitive Sensor Channel 0 Increasing Threshold Trigger
0x0006 = Capacitive Sensor Channel 0 Decreasing Threshold Trigger
0x0007 = Capacitive Sensor Channel 1 Increasing Threshold Trigger

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0x0008 = Capacitive Sensor Channel 1 Decreasing Threshold Trigger

Example 1:

An accelerometer packet in basic raw format and with X = +1mg Y = -1mg and Z = +1000mg would look like –

```
0x7F 0x7F 0x7E 0x01 0x00 0xFF 0xFF 0xE8 0x03
```

Example 2:

A navigation switch pressed up event packet would look like –

```
0x7F 0x7F 0x76 0x02 0x00
```

Example 3:

An accelerometer packet in time-stamped raw format with a time stamp of 97.66mS and with X = +5mg Y = -2mg and Z = +1000mg would look like –

```
0x7F 0x7F 0x7E 0x05 0x00 0xFE 0xFF 0xE8 0x03 0x0A 0x00
```

Example 4:

An accelerometer packet in “vibration motor voltage” raw format with a vibration motor voltage of 0x80 when the packet was created and with X = +3mg Y = -2mg and Z = +1000mg would look like –

```
0x7F 0x7F 0x7E 0x03 0x00 0xFE 0xFF 0xE8 0x03 0x80
```

SK6 Control Registers.

Command Packets Skeleton Structure

The command packets take on a format that is also very similar to that used by the NMEA protocol (common is GPS devices). This should allow the partial re-use of source code already developed for NMEA.

Note: The command packets format are universal for ALL commands, regardless of whether the data output packets are in the default ASCII mode or the raw data mode.

The packets take the following format:

$packetID,address,data

Where packetID is a three character field unique to the packet type, and is “REA” for a read, and “WRI” for a write packet

Address is the 4 digit Hex register address field, data is the two digit data field.

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Write Command Packet

The write command packet takes the general format -

`$WRI,hhhh,zz`

Where `hhhh` represents the register address field in hexadecimal represented as ASCII.

And `zz` is the data, which must be in the data format that the register accepts, see the

For the event packets, the number output will be as follows –

0x0001 = Navigation Switch released
0x0002 = Navigation Switch pressed UP
0x0003 = Navigation Switch pressed DOWN
0x0004 = Navigation Switch pressed CENTRE

0x0005 = Capacitive Sensor Channel 0 Increasing Threshold Trigger
0x0006 = Capacitive Sensor Channel 0 Decreasing Threshold Trigger
0x0007 = Capacitive Sensor Channel 1 Increasing Threshold Trigger
0x0008 = Capacitive Sensor Channel 1 Decreasing Threshold Trigger

Example 1:

An accelerometer packet in basic raw format and with X = +1mg Y = -1mg and Z = +1000mg would look like –

`0x7F 0x7F 0x7E 0x01 0x00 0xFF 0xFF 0xE8 0x03`

Example 2:

A navigation switch pressed up event packet would look like –

`0x7F 0x7F 0x76 0x02 0x00`

Example 3:

An accelerometer packet in time-stamped raw format with a time stamp of 97.66mS and with X = +5mg Y = -2mg and Z = +1000mg would look like –

`0x7F 0x7F 0x7E 0x05 0x00 0xFE 0xFF 0xE8 0x03 0x0A 0x00`

Example 4:

An accelerometer packet in “vibration motor voltage” raw format with a vibration motor voltage of 0x80 when the packet was created and with X = +3mg Y = -2mg and Z = +1000mg would look like –

`0x7F 0x7F 0x7E 0x03 0x00 0xFE 0xFF 0xE8 0x03 0x80`

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SK6 Control Registers section for the data format specific to that address.

Total packet length = 15bytes

Example:

To write a value of value of 0x20 to the configuration resister the has address 0x0012, then the following command string would be sent –

```
$WRI,0012,20
```

Read Command Packet

The read command packet takes the general format -

```
$REA,hhhh,00
```

Where hhhh represents the register address field in hexadecimal represented as ASCII.

The data value in the register addressed is returned in an Acknowledge/Response packet. See the

For the event packets, the number output will be as follows –

0x0001 = Navigation Switch released
0x0002 = Navigation Switch pressed UP
0x0003 = Navigation Switch pressed DOWN
0x0004 = Navigation Switch pressed CENTRE

0x0005 = Capacitive Sensor Channel 0 Increasing Threshold Trigger
0x0006 = Capacitive Sensor Channel 0 Decreasing Threshold Trigger
0x0007 = Capacitive Sensor Channel 1 Increasing Threshold Trigger
0x0008 = Capacitive Sensor Channel 1 Decreasing Threshold Trigger

Example 1:

An accelerometer packet in basic raw format and with X = +1mg Y = -1mg and Z = +1000mg would look like –

```
0x7F 0x7F 0x7E 0x01 0x00 0xFF 0xFF 0xE8 0x03
```

Example 2:

A navigation switch pressed up event packet would look like –

```
0x7F 0x7F 0x76 0x02 0x00
```

Example 3:

An accelerometer packet in time-stamped raw format with a time stamp of 97.66mS and with X = +5mg Y = -2mg and Z = +1000mg would look like –

```
0x7F 0x7F 0x7E 0x05 0x00 0xFE 0xFF 0xE8 0x03 0x0A 0x00
```

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Example 4:

An accelerometer packet in "vibration motor voltage" raw format with a vibration motor voltage of 0x80 when the packet was created and with X = +3mg Y = -2mg and Z = +1000mg would look like –

```
0x7F 0x7F 0x7E 0x03 0x00 0xFE 0xFF 0xE8 0x03 0x80
```

SK6 Control Registers section for details of accessible registers to read.

Total packet length = 15bytes

The SK6 Acknowledge / Response Packets

These packets are always sent from the SHAKE device back to the host in response to command packets. There are two types, an Acknowledge packet and a not-Acknowledge packet. An Acknowledge packet is sent upon receipt of command packet if the command's address and data fields were valid and were successfully written to or read from the register that was addressed. A not-Acknowledge packet is returned when either the address or data fields of the command packet are not valid or are out of bounds.

Acknowledge Packet / Not-Acknowledge Packets

With the time stamp feature disabled (see configuration bit in Table 10 - Data Output Format Register for enabling packet time stamps in raw data mode and in the ACK and NAK packets), the packet format is

```
$ACK,hhhh,zz*CS[CR][LF]
$NAK,hhhh,zz*CS[CR][LF]
```

With time stamps enabled the packet format is –

```
$ACK,hhhh,zzTTT[CR][LF]
$NAK,hhhh,zzTTT[CR][LF]
```

These packet contains the address and data value of the register that was accessed in the command packet that generated this acknowledge / not-acknowledge.

Where hhhh represents the register address field in hexadecimal represented as ASCII.

And ZZ is the data, which will be in the data format that the register, see the register spreadsheet for the data format specific to that address.

TTT is the time stamp (if enabled), and is in decimal format rolling over every 1000 counts. The value is the time stamp in units of 1/102.4 seconds, thus the time stamp resets about every 10 seconds.

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Total packet length = 17 bytes with the checksum or timestamp enabled, 14 bytes otherwise.

Response Packets Example

If a Write command was issued to update a value of 0x20 to the configuration resister that has address 0x0014, then the following command string would be sent –

```
$WRI,0014,20[CR][LF]
```

Where [CR] represents the byte value 0x0D and [LF] the value 0x0A

And if successful the following would be returned (if checksum disabled) -

```
$ACK,0014,20[CR][LF]
```

If not successful, the following would be returned (if checksum disabled) –

```
$NAK,0014,20[CR][LF]
```

The reason for the unsuccessful command is not given in the current implementation of this protocol.

SK6 Example Commands

This section gives a few examples of the text strings that can be sent to the SK6 to perform certain functions.

Example 1: To change the output data rate (ODR) of the acceleration data to 50Hz

Send this string -

```
$WRI,0008,32
```

If successful, then this response should be given –

```
$ACK,0008,32
```

If unsuccessful, then this response should be given –

```
$NAK,0008,32
```

Example 2: To change the output data rate (ODR) of the acceleration data to 100Hz

```
$WRI,0008,64
```

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Example 3: To change the output data rate (ODR) of the magnetometer data to 15Hz

```
$WRI,000A,0F
```

Example 4: To Request the battery charge level

```
$REA,0105,00
```

If successful, then this response should be given –

```
$ACK,0105,98
```

Where the battery level is (0x98/0xFF) * 100 in percent, or 59.6%

Example 5: To Request the internal temperature of the SK6

```
$REA,0107,00
```

If successful, then this response should be given –

```
$ACK,0107,64
```

Where the temperature is 0x64 * 0.25 = 25degC

Example 6: To Power the Accelerometer, Magnetometer and Vibration display and power down all other sensors

```
$WRI,0000,1A
```

If successful, then this response should be given –

```
$ACK,0000,1A
```

Example 7: To Enable the minimum phase digital filter on the acceleration data

```
$WRI,0014,03
```

If successful, then this response should be given –

```
$ACK,0014,03
```

Example 8: To Start Data Logging Recording

```
$WRI,010D,04
```

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If successful, then this response should be given –

```
$ACK,010D,04
```

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The SK6 Data Packets in Raw (Binary) mode

The SK6 data is optionally available to be output in raw (binary) mode. This is a preferable method of data output as it reduces the bandwidth requirements by as much as 80%. This reduces signal latency (especially over Bluetooth connection) of both sensor signals and vibration trigger commands. It also allows higher data rates to be achieved.

The header of the raw data packets consists of three bytes, the first two of which are always 0x7F. Data fields are always 16 bit 2's complement integer format and the least significant byte (LSB) always precedes the most significant byte (MSB) – see Table 5. The two optional fields are 8bit (byte) fields.

All of the data ranges for the values encapsulated by these packets are the same as those of the equivalent ASCII data packets described above. All acknowledge packets are still returned in ASCII mode when raw mode is selected for the data packets. The output data in these packets is limited to 14bits or less and as such the sequences of the two header bytes for any of these packets cannot possibly happen within the data fields.

The raw packets can take a number of different formats, selectable by setting the appropriate bit in Table 10 - Data Output Format Register.

1) Basic Raw data packets
2) Raw data packets with packet counter field
3) Raw data packets with time stamp field
4) Raw data packets with vibration motor voltage field

Please note that only the basic raw data packets are currently available for the Event type packets.

1) Basic Raw data packets

The format is shown in Table 5. This format is selected by setting the register 0x0002 (Table 10 - Data Output Format Register) to 0x02. Neither of the optional fields are present in this format so the total packet length is 9 bytes.

2) Raw data packets with packet counter field

The packet count is inserted in optional field #1. It counts 0 to 0xFF repeatedly but skips the value 0x7F. Option field #2 is not present. This format is selected by setting the register 0x0002 (Table 10 - Data Output Format Register) to 0x06.

3) Raw data packets with time stamp field

The timestamp is contained in optional field #1 (LSByte) and optional field #2 (MSByte). This time stamp indicates the time in 1/102.4 of a second, and resets every 1000 counts. Thus the timestamp circulates approximately every 10 seconds. This format is selected by setting the register 0x0002 (Table 10 - Data Output Format Register) to 0x0A.

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4) Raw data packets with vibration motor voltage field

The voltage that is applied to the vibration motor at the time the data packet is created is contained in optional field #1 (Option field #2 is not present). This is useful to know for certain applications that rely on the accelerometer, magnetometer or gyro sensors as the vibration can add noise and a small amount error to those signals. Thus packets that have a non-zero value for the vibration voltage field could be deemed to be less than certainly accurate, allowing the target application to take steps to compensate for.

The value is normalized to 255, and if it is greater than zero the vibration motor has started vibrating. It takes about 5mS for the internal vibration motor to spin up to full speed, and can take 100mS to spin down if the brake is not applied in the vibration profile. The spin up and spin down periods are more likely to add a small error to the inertial sensor signals, as these are the periods of asymmetrical jerk. If the vibration motor is spinning at a steady state, then the interference is easily filtered out with the on board digital filters.

This format is selected by setting the register 0x0002 (Table 10 - Data Output Format Register) to 0x0E.

	Header Byte #1	Header Byte #2	Header Byte #3	Data Field #1	Data Field #2	Data Field #3	Optional Field #1	Optional Field #2
Accelerometer Packet	0x7F	0x7F	0x7E	X	Y	Z	See Text	See Text
Angular rate Packet	0x7F	0x7F	0x7D	Pitch	Roll	Yaw	See Text	See Text
Magnetometer Packet	0x7F	0x7F	0x7C	X	Y	Z	See Text	See Text
Compass Heading Packet	0x7F	0x7F	0x7B	Heading			See Text	See Text
Capacitive Sensor Channel 0 Packet	0x7F	0x7F	0x7A	Proximity			See Text	See Text
Capacitive Sensor Channel 1 Packet	0x7F	0x7F	0x79	Proximity			See Text	See Text
Analog Input Channel 0 Packet	0x7F	0x7F	0x78	Voltage			See Text	See Text
Analog Input Channel 1 Packet	0x7F	0x7F	0x77	Voltage			See Text	See Text
Event Packet	0x7F	0x7F	0x76	Event Type				

Table 5 – Output Data Packets in Raw (Binary) mode

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For the event packets, the number output will be as follows –

0x0001 = Navigation Switch released
0x0002 = Navigation Switch pressed UP
0x0003 = Navigation Switch pressed DOWN
0x0004 = Navigation Switch pressed CENTRE

0x0005 = Capacitive Sensor Channel 0 Increasing Threshold Trigger
0x0006 = Capacitive Sensor Channel 0 Decreasing Threshold Trigger
0x0007 = Capacitive Sensor Channel 1 Increasing Threshold Trigger
0x0008 = Capacitive Sensor Channel 1 Decreasing Threshold Trigger

Example 1:

An accelerometer packet in basic raw format and with X = +1mg Y = -1mg and Z = +1000mg would look like –

```
0x7F 0x7F 0x7E 0x01 0x00 0xFF 0xFF 0xE8 0x03
```

Example 2:

A navigation switch pressed up event packet would look like –

```
0x7F 0x7F 0x76 0x02 0x00
```

Example 3:

An accelerometer packet in time-stamped raw format with a time stamp of 97.66mS and with X = +5mg Y = -2mg and Z = +1000mg would look like –

```
0x7F 0x7F 0x7E 0x05 0x00 0xFE 0xFF 0xE8 0x03 0x0A 0x00
```

Example 4:

An accelerometer packet in “vibration motor voltage” raw format with a vibration motor voltage of 0x80 when the packet was created and with X = +3mg Y = -2mg and Z = +1000mg would look like –

```
0x7F 0x7F 0x7E 0x03 0x00 0xFE 0xFF 0xE8 0x03 0x80
```

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SK6 Control Registers

Configuration Registers

The SK6 is highly configurable. Configuration is achieved by writing to a set of configuration registers using the command packets. Please see the section titled The SK6 Command Packets for the format of the command packets.

Power Control Configuration Register #1 Address 0x0000

Register Bit-fields:	Purpose:	Function:	Factory Default:	Current Consumption Delta [mA] :
Bit 0	Capacitive Sensing	0 = Disable 1 = Enable	1	NYD
Bit 1	Accelerometer	0 = Disable 1 = Enable	1	0.5
Bit 2	Angular Rate Sensor[10]	0 = Disable 1 = Enable	0	12
Bit 3	Vibrotactile Drivers	0 = Disable 1 = Enable	1	NYD
Bit 4	Magnetometer	0 = Disable 1 = Enable	1	2
Bit 5	Temperature	0 = Disable 1 = Enable	1	NYD
Bit 6	Analog Inputs	0 = Disable 1 = Enable	1	NYD
Bit 7	Navigation Switch	0 = Disable 1 = Enable	1	0

Table 6 - Power Control Configuration Register #1

[10] Angular Rate Sensor module (SK6-G01) must be installed for this to operate

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Power Control Configuration Register #2 Address 0x0001

Register Bit-fields:	Purpose:	Function:	Factory Default:
Bit 0	CS0 Increasing Trigger Vibration	0 = Disable 1 = Enable	0
Bit 1	CS0 Decreasing Trigger Vibration	0 = Disable 1 = Enable	0
Bit 2	CS1 Increasing Trigger Vibration	0 = Disable 1 = Enable	0
Bit 3	CS1 Decreasing Trigger Vibration	0 = Disable 1 = Enable	0
Bit 4	Data Output Packet Enable for Capacitive Sensing Trigger Mode	0 = Disable 1 = Enable	0
Bit 5	Reserved	0 = Disable 1 = Enable	0
Bit 6	Reserved	0 = Disable 1 = Enable	0
Bit 7	Reserved	0 = Disable 1 = Enable	0

Table 7 - Power Control Configuration Register #2

Communications Configuration Register Address 0x0003

Register Bit-fields:	Purpose:	Function:	Factory Default:
Bit 0	Bluetooth Security	0 = Disable 1 = Enable	0
Bit 1	Reserved	0 = Disable 1 = Enable	0
Bit 2	Reserved	0 = Disable 1 = Enable	0
Bit 3	Reserved	0 = Disable 1 = Enable	0
Bit 4	Reserved	0 = Disable 1 = Enable	0
Bit 5	Reserved	0 = Disable 1 = Enable	0
Bit 6	Reserved	0 = Disable 1 = Enable	0
Bit 7	Reserved	0 = Disable 1 = Enable	0

Table 8 - Communications Configuration Register

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Accelerometer Configuration Register #1 Address 0x0004

Register Bit-fields:	Purpose:	Function:	Factory Default:	Current Consumption Delta [mA] :
Bit 0	Acceleration Measurement Range	0 : +/- 2g 1 : +/- 6g	0	0
Bit 1	High Pass Filter	0 : Disable 1 : Enable	0	NYD
Bit 2	reserved		0	
Bit 3	reserved		0	
Bit 4	reserved		0	
Bit 5	reserved		0	
Bit 6	reserved		0	
Bit 7	reserved		0	

Table 9 - Accelerometer Configuration Register #1

Data Output Format Register Address 0x0002

Register Bit-fields:	Purpose:	Function:	Factory Default:
Bit 0	ASCII Data Checksum	0 : Disabled 1 : Enabled	0
Bit 1	ASCII / Raw output data format select	0 : ASCII 1 : Raw	0
Bit 3:2	Raw Packet Type	00 : Basic 01 : Counter Field Enabled 10 : Timestamp Field Enabled 11 : Vibration Motor Voltage Field enabled	00
Bit 4	reserved		0
Bit 5	reserved		0
Bit 6	reserved		0
Bit 7	reserved		0

Table 10 - Data Output Format Register

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Digital Filter Control Registers

Register Name	Register Address	Default Value	Valid Data Range	Function:
Acceleration Filter Properties	0x0014	0x01	bit 0: 0 = Filter Disabled 1 = Filter Enabled bit 1: 0 = Linear Phase 1 = Minimum Phase bits 2 to 7 : Reserved	To enable / disable the digital filter for the selected channel and to select the filter type between a linear phase FIR filter or a minimum phase (minimum group delay) FIR filter
Angular Rate Filter Properties[1]	0x0015	0x01		
Magnetometer Filter Properties	0x0016	0x01		
Compass Heading Averaging (see Compass Heading Sensor Section)	0x0017	0x00		
Capacitive Sensor Ch. 0 Filter Properties	0x0018	0x01		
Capacitive Sensor Ch. 1 Filter Properties	0x0019	0x01		
Analog Input Ch. 0 Filter Properties	0x001A	0x01		
Analog Input Ch. 1 Filter Properties	0x001B	0x01		

Table 11 - Digital Filter Control Registers

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Output Data Rate Control Registers

Register Name	Register Address	Default Value [Hz]	Valid Data Range	Function:
Acceleration ODR	0x0008	5	With Digital Filter Disabled : 0 to 255 With Digital Filter Enabled : 0 to 24 inclusive and the values listed for ODR in Table 3	To control the rate in packets per second at which the SK6 outputs the sensor data packets. If set to 0, the respective data channel is disabled.
Angular Rate ODR [11]	0x0009	0		
Magnetometer ODR	0x000A	0		
Compass Heading ODR	0x000B	0		
Capacitive Sensor Ch. 0 ODR	0x000C	0		
Capacitive Sensor Ch. 1 ODR	0x000D	0		
Analog Input Ch. 0 ODR	0x000E	0		
Analog Input Ch. 1 ODR	0x000F	0		

Table 12 - Output Data Rate Control Registers

Data Output Calibration Bypass Register Address 0x0006

Register Bit-fields:	Channel:	Function:	Factory Default:
Bit 0	Acceleration	**0** : Data modified by calibration constants **1** : Data not modified, output is un-calibrated	0
Bit 1	Angular Rate (Gyros)		0
Bit 2	Magnetic Field Strength		0
Bit 3	Reserved		0
Bit 4	Capacitive Sense Ch. 0		0
Bit 5	Capacitive Sense Ch. 1		0
Bit 6	External Analog Input Ch. 0		0
Bit 7	External Analog Input Ch. 1		0

Table 13 - Data Output Calibration Bypass Register

[11] Angular Rate Sensor module (SK6-G01) must be installed for this to operate

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Data Output Cross-Axes Calibration Bypass Register Address 0x0007

Register Bit-fields:	Channel:	Function:	Factory Default:
Bit 0	Acceleration	**0** : Data modified by cross axes calibration constants **1** : Data not modified by cross axes calibration coefficients	0
Bit 1	Angular Rate (Gyros)		0
Bit 2	Magnetic Field Strength		0
Bit 3	Reserved		0
Bit 4	Reserved		0
Bit 5	Reserved		0
Bit 6	Reserved		0
Bit 7	Reserved		0

Table 14 - Data Output Cross Axes Calibration Bypass Register

Data Packet Streaming Disable Register Address 0x0012

Register Bit-fields:	Channel:	Function:	Factory Default:
Bit 0	Acceleration	**0** = Output Packet Streaming Enabled **1**: Output Packet Streaming Disabled	0
Bit 1	Angular Rate (Gyros)		0
Bit 2	Magnetic Field Strength		0
Bit 3	Compass Heading		0
Bit 4	Capacitive Sense Ch. 0		0
Bit 5	Capacitive Sense Ch. 1		0
Bit 6	External Analog Input Ch. 0		0
Bit 7	External Analog Input Ch. 1		0

Table 15 – Data Packet Streaming Disable Register

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Temperature Compensation Enable Register Address 0x0010

Register Bit-fields:	Channel:	Function:	Factory Default:
Bit 0	Reserved	**0** = Output Packet Temperature Compensation Disabled **1**: Output Packet Temperature Compensation Enabled	0
Bit 1	Angular Rate (Gyros)		0
Bit 2	Reserved		0
Bit 3	Reserved		0
Bit 4	Reserved		0
Bit 5	Reserved		0
Bit 6	Reserved		0
Bit 7	Reserved		0

Table 16 –Temperature Compensation Enable Register

Capacitive Sensing Trigger Mode Control Registers

Register Name / Function	Register Address	Default Value	Valid Data Range
CS0 Increasing Trigger Threshold	0x0028	0x00	0 to 255
CS0 Decreasing Trigger Threshold	0x0029	0x00	
CS0 Increasing Trigger Vibration Profile Playback	0x002A	0x00	
CS0 Decreasing Trigger Vibration Profile Playback	0x002B	0x00	
CS1 Increasing Trigger Threshold	0x002C	0x00	
CS1 Decreasing Trigger Threshold	0x002D	0x00	
CS1 Increasing Trigger Vibration Profile Playback	0x002E	0x00	
CS1 Decreasing Trigger Vibration Profile Playback	0x002F	0x00	

Table 17 - Capacitive Sensing Trigger Mode Control Registers

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SK6 Request Registers

The SK6 Request registers are write-only virtual registers that allow the host to command the SK6 to perform a particular task (such as sending a particular sensor data packet or triggering a particular vibration profile). Such requests are achieved by writing to these registers using the command packets. Please see the section titled The SK6 Command Packets for the format of the command packets.

Data Request Register #1 Address 0x0100

Register Bit-fields:	Purpose:	Function:
Bit 0	Acceleration Data	0 : no action 1 : send a data packet
Bit 1	Angular Rate Data[12]	0 : no action 1 : send a data packet
Bit 2	Magnetometer Data	0 : no action 1 : send a data packet
Bit 3	Compass Heading Data	0 : no action 1 : send a data packet
Bit 4	Capacitive Sensor Ch. 0	0 : no action 1 : send a data packet
Bit 5	Capacitive Sensor Ch. 1	0 : no action 1 : send a data packet
Bit 6	Analog Input Ch. 0	0 : no action 1 : send a data packet
Bit 7	Analog Input Ch. 1	0 : no action 1 : send a data packet

Table 18 - Data Request Register #1

Data Request Register #2 Address 0x0101

Register Bit-fields:	Purpose:	Function:
Bit 0	Output Start-up Splash	0 : no action 1 : send the start-up splash text (firmware revision, hardware revision etc.)
Bits 1-7	reserved	

Table 19 - Data Request Register #2

[12] Angular Rate Sensor module (SK6-G01) must be installed for this to operate

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Vibration Request Registers

Register Name	Register Address	Valid Data Range	Function:
Vibration Main	0x0102	0x00 to 0xFF	Play vibration profile number on the internal vibrating motor
Vibration Left[13]	0x0103	0x00 to 0xFF	Play vibration profile number on the external left vibrating motor
Vibration Right[2]	0x0104	0x00 to 0xFF	Play vibration profile number on the external right vibrating motor
Linear Vibration Left[14]	0x0126	0x00 to 0xFF	Output a 170Hz pulsed waveform to drive a linear vibration actuator, see page 63 for details
Linear Vibration Right[2]	0x0127	0x00 to 0xFF	Output a 170Hz pulsed waveform to drive a linear vibration actuator, see page 63 for details

Table 20 - Vibration Request Registers

Calibration Request Register Address 0x010A

Value:	Purpose:
0	Do nothing
1	Enter magnetometer calibration mode
2	Enter accelerometer calibration mode
3	Enter angular rate sensor calibration mode[15]
4	Enter temperature calibration mode
5	Enter battery calibration mode
6	Enter capacitive sensor calibration mode
7	Enter external analog input calibration mode

Table 21 - Calibration Request Register #1

Data Logging Command Register Address 0x010D

Register	Command Name:	Function:

[13] For the external vibration functionality the SK6-V01 module must be installed
[14] For the external vibration functionality the SK6-V01 module must be installed
[15] Angular Rate Sensor module (SK6-G01) must be installed for this to operate

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Value:		
1	PLAY	Starts serially streaming the contents of the data logging memory from the start of the memory space
2	PAUSE	Pauses data logging in either play mode or record mode
3	STOP	Stops data logging in either play mode or record mode and resets the read / write pointer back to the beginning of memory
4	RECORD	Starts recording all the data sensors configured for output to memory
5	TIMER_RESET	Resets the data logging timestamp clock to zero (but only if recording is not already in progress)
6	Reserved	
7	Reserved	
8	Reserved	

Table 22 – Data Logging Command Register

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SK6 Query Registers

The SK6 Query registers are read only volatile registers that allow the host to interrogate the SK6 for particular information such as the battery level or the device temperature. Such queries are achieved by reading from these registers using the command packets. Please see The SK6 Command Packets section for the format of the command packets.

Power Status Register Address 0x0106

Register Bit-fields:	Purpose:	Function:
Bit 0	External Power Status	0 : Charger is not connected 1 : Charger is connected
Bit 1	Battery Charging Status	0 : Battery is not charging 1 : Battery is charging
Bit 2	Battery Full Status	0 : Battery is not fully charged 1 : Battery is fully charged
Bits 3-7	reserved	

Table 23 - Power Status Register

Battery Level Register

Register Name	Register Address	Valid Data Range	Function:
Battery Level	0x0105	0x00 == Empty 0xFF == Full	Read the battery charge level

Table 24 - Battery Level Register

Temperature Register

Register Name	Register Address	Valid Data Range	Function:
Temperature	0x0108	0x00 == 0degC 0xFF == 64degC	Read the SK6 onboard temperature in 0.25degC steps.

Table 25 - Temperature Register

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Data Logging Status Register Address 0x010E

Register Bit-fields:	Flag Name:	Function:
Bit 0	Record Flag	Reads 1 when data logging is in record mode, reads 0 otherwise
Bit 1	Play Flag	Reads 1 when data logging is in playback mode, reads 0 otherwise
Bit 2	Memory Almost Full Flag	Reads 1 if the data logging memory is almost full (<1% available), reads 0 otherwise
Bits 3-7	Reserved	

Table 26 – Data Logging Status Register

Data Logging Memory Space Remaining Register

Register Name	Register Address	Valid Data Range	Function:
DL Space Remaining	0x0110	0x00 == Empty 0xFF == Full	While data logging in record mode, read this register to gauge the proportion of memory still remaining

Table 27 - Data Logging Memory Space Remaining Register

Data Logging Number of Data Packets Recorded Registers (non- volatile)

Register Name	Register Address	Function:
DL Num Packets Written LSB	0x0038	This register pair contains the value of the number of packets divided by 100 already recorded to memory. Num Packets Written = 100*(MSB*256 + LSB)
DL Num Packets Written MSB	0x0039	

Table 28 - Data Logging Number of Data Packets Recorded Registers

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LED colour override registers

Register Name	Register Address	Valid Data Range	Function:
LED override – RED component	0x011B	0x00 == no override 0x01 - 0xFF == Brightness	Override the LED internal display function
LED override – GREEN component	0x011C	0x00 == no override 0x01 - 0xFF == Brightness	Override the LED internal display function
LED override – BLUE component	0x011D	0x00 == no override 0x01 - 0xFF == Brightness	Override the LED internal display function

Table 29 - LED colour override registers

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SK6 External Analog Inputs

The SK6 allows for up to two external analog signals to be sampled. The specification of the sampling is detailed in Table 30

Parameter	Min	Nominal	Max
Sample Rate [Hz]	1024	**1024**	1024
Sample Resolution [bits]	11	**11.5**	12
Analog Lowpass Filter -3dB Corner Frequency [Hz]	160	**167**	174
Analog Lowpass Filter Attenuation at Nyquist [dB]	-10dB	**-11dB**	-12dB
Input Voltage Range [Volts]	0 to 2.7	**0 to 2.75**	0 to 2.8
Output Counts per Volt	980	**1000**	1020
Input Impedance at DC [kOhm]	105	**110**	115
Input Impedance at 100Hz [kOhm]	22	**25**	28
Input Over Voltage Tolerance [Volts] (0 to 10kHz)		**+ / - 8**	
DC Supply Voltage on Aux Connector Tip [Volts]	2.9	**3**	3.1
DC Supply Voltage Current Rating [mA]		**10**	12
DC Supply Voltage Output Impedance [ohm]	1	**1.5**	2

Table 30 - External Analog Inputs Specifications

These analog inputs are available through the Aux connector (1) on the front of the SK6. This is a 2.5mm 4-pole socket that will accept a 2.5mm 4-pole jack. A cable assembly with such a jack is available from CUI Inc through http://www.digikey.com part number CP-254S-ND.

Figure 17 - Digikey Part CP-254S-ND for connecting external analog signals to the SK6

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This provides the 4 required connections to stripped and tinned exposed wires (do not connect the blue wire). The connections are as follows –

A : +3V DC Supply (max 10mA)
B : Analog Input Channel 1 (also UART RX)
C : Analog Input Channel 0 (also UART TX)
D : Common Ground (0V)

The +3V supply is not protected from short circuits. A short circuit on this line may cause the SK6 to reset or even crash. If this should happen, cycle the power switch (2) of the SK6 for a few seconds to ensure a clean reset. Under no circumstances should the +3V line be back fed with any voltage outside the range 2.9V to 3.1V. Doing so may damage the SK6.

The +3V supply is useful if one needs to connect an external sensor circuit. If the external circuit has active electronics, then this line can drive the Vdd line of that circuit as long as the current consumption is no more than 10mA peak. Alternatively, this supply line can be used to drive the top resistor in a potential divider where the bottom resistor element is the sensor (a thermistor, a light dependant resistor (LDR), a force sensor or a bend sensor could all be used in this situation). For example, to connect a thermistor, use the following circuit –

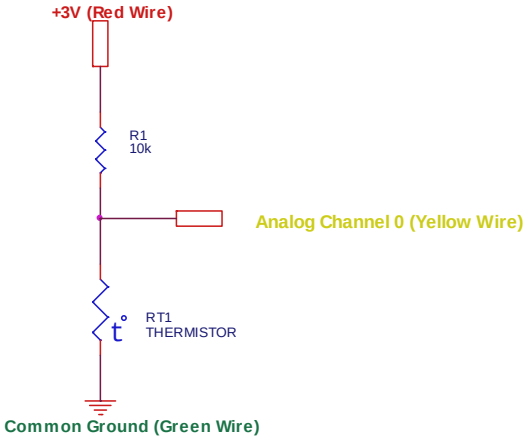

Figure 18 - Connecting a resistive sensor to the SK6

The optimum value for R1 will depend on the sensor used and the measurement range required.

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SK6 External Vibration Driver Module, SK6-V01

The optionally available SK6-V01 module allows up to two external vibration motors to be connected to the SHAKE via the Aux connector (1) using the supplied cable depicted in Figure 19. The motors must be rated so that the steady state maximum current drain is 100mA at 3V. Most off-the-shelf pager motors that are rated for 3V operation will meet this criterion. The motors should be connected as depicted in the schematic of Figure 20. The operation of the drive electronics is the same as that for the internal vibration motor – they can be triggered to play back any uploaded vibration profiles.

Additionally, with firmware versions 2.50 and above, linear actuators can be driven with a pulsed waveform at a fixed frequency of 170Hz. A single byte written to either volatile configuration register 0x0126 (Left Channel) or 0x0127 (Right Channel) triggers a pulsed output to the actuator. The two most significant bits of the byte sent represent the amplitude of the pulses, and the 6 least significant bits represent the time for which the pulses are sent. These time lengths are in multiples of 26ms, with the maximum pulse time length 63 * 26ms = 1.66s. The amplitude levels are 0%, 33%, 66% and 100% corresponding to amplitude bits 0b00, 0b01, 0b10, 0b11 respectively. For example to send a brief 26ms pulse to the left channel external vibration transducer at full amplitude send this –

```
$WRI,0126,C1
```

If successful, then this response should be given –

```
$ACK,0126,C1
```

As another example, to send a long pulse of 1.66 seconds at full amplitude to the right channel send this –

```
$WRI,0127,FF
```

If successful, then this response should be given –

```
$ACK,0127,FF
```

Note: As this module requires the use of the Aux connector, it can not be used at the same time as the external analog inputs or the SK6-USB serial cable.

Pulsed drive and vibration profiles

With firmware versions 2.60 and above, the standard vibration profiles can be used to drive pulsed waveforms to the externally connected actuators. The vibration profile is the same format as for the main motor except that the reserved fields now are used to control the frequency and duty cycle of the pulsed waveform. The profile format is –

$VIB,addr,mode,freq,duty,amp1,end1,amp2,end2.....,ampN,endN~

Where *addr* is a fixed width two digit hex number from 1 to 255 (01 to FF) representing the address of the location that the profile is to be written to. Address space 00 is reserved and cannot be written to.

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mode is a fixed width 2 hex field representing the mode of drive when the profile is triggered. For pulsed drive, this field must be set to the value 02

freq is a fixed width 2 hex field representing the frequency of the pulsed waveform. The output frequency is twice this value. For example if 250Hz is required, then the value should be set to 7D

duty is a fixed width 2 hex field representing the duty ratio of the pulsed output. The range of values is 1 to 9 representing 10% to 90% duty ratio respectively.

amp1 is a fixed width 2 hex field representing the amplitude of the output. Set this field to FF for maximum amplitude.

end1 is a fixed width 2 digit hex number representing the end time of the *amp1* value and the time at which the amp2 value will be applied to the motor. A value of zero will cause the playback to cease and subsequent elements in the profile will be ignored. Each unit represents 10mS of time so the range is from 10mili seconds to 2.55 seconds

The last character must be a ~, this indicates to the SK6 that the end of the packet has been reached.

Example:

To upload a vibration profile to address space number 10 (0x0A) that drives the actuator with a pulsed waveform that is full amplitude for the first 200mS, at half amplitude for the next 200mS, all at a frequency of 250Hz and duty ratio of 50% you would send the following packet –

```
$VIB,0A,02,7D,05,FF,14,7F,14,00,00~
```

The SK6 will respond with (if checksum is disabled) -

```
$ACK,VIB ,00[CR][LF]
```

if successful or

```
$NAK,VIB ,00[CR][LF]
```

if unsuccessful

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Figure 19 - Digikey Part CP-254S-ND for connecting up to two external vibration pager motors to the SK6

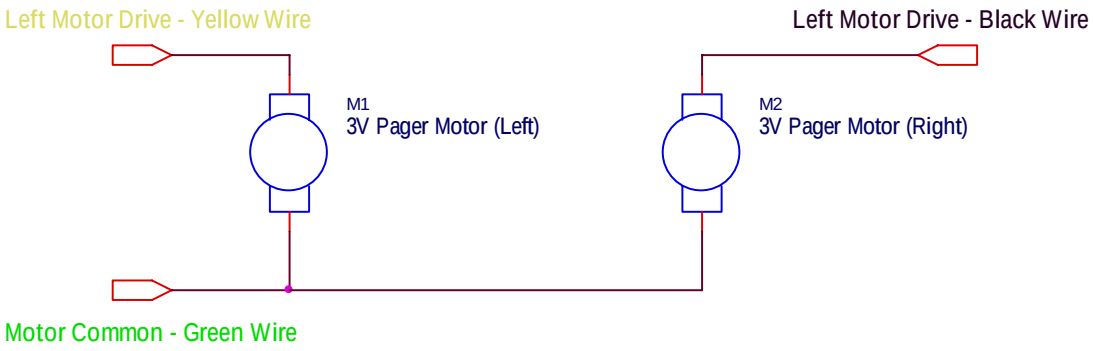

Figure 20 – SK6-V01 External Vibration Motors connection schematic

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SK6 Polar Heart Rate Monitor Receiver Module, SK6-H01

The optionally available SK6-H01 module provides reception of the pulses from the Polar range of heart rate monitor chest straps, such as the T61. Once enabled, a data packet will be output every time a heart beat is detected.

The polar chest straps usually come in two types – coded and non-coded. This module does not provide code decoding, and as such either type of strap will suffice. Please be aware however that this module will not work with the new generation of 2.4GHz transmitters.

Direct pulse feedback can be enabled, where every heart pulse can trigger a red flash of the LED, or a brief vibration or both. Please see Table 32 for details.

The range of reception is quite sensitive to the relative orientations of the chest strap and the SHAKE. For maximum sensitivity, the long axis of the SHAKE (the X-axis) should be aligned such that it is parallel to the tangent of the belt.

The receiver is very sensitive to alternating magnetic fields and shock vibrations, and as such triggering vibration samples can cause false triggers. It is recommended that vibration feedback is not used while measuring heart rate, except for the Pulse Vibration Feedback (see Table 32) which is designed so as not to interfere.

This module will only operate with V1.40 of the SHAKE SK6 hardware, and with firmware versions 2.10 or higher.

The heart rate output packet takes the form

```
$HR ,dddd,dd*CS[CR][LF]
```

Where the field dddd is the heart rate in beats per minute (BPM) in deimal format

And the dd field is the timestamp field, see section The SK6 Data Packets for details.

Parameter	Min	Typical	Max
Heart Rate Range [BPM]	25	~	240
Reception Range[inches] (when used with the T61)	14	16	18

Table 31 – SK6-H01 Heart Rate Monitor Receiver Module Specifications

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Heart Rate Module Configuration Register #1 address 0x003A

Register Bit-fields:	Purpose:	Function:	Factory Default:
Bit 0	H01 Module Power	0 : Disabled 1 : Enabled	Unknown
Bit 1	Pulse Visual Feedback	0 : Disabled 1 : Enabled	Unknown
Bit 2	Pulse Vibration Feedback	0 : Disabled 1 : Enabled	Unknown
Bit 3	reserved		Unknown
Bit 4	reserved		Unknown
Bit 5	reserved		Unknown
Bit 6	reserved		Unknown
Bit 7	reserved		Unknown

Table 32 – Heart Rate Module Configuration Register #1

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SK6 Firmware Upgrade

Warning: It is important that this procedure is not interrupted. If it is, the SK6 may be bricked.
Note: It is important to have the SK6 very close (<20cm) from the host Bluetooth antenna to minimize the chances of a dropped connection during this procedure.
Note: These direction apply to the MS Windows XP platform only

Note: This procedure does not affect the calibration or configuration of the SHAKE.

Firmware Upgrade Procedure:

1) Connect the charger to the mains and plug it into the SK6

2) Turn the power switch (2) to the Off position for 2 or more seconds

3) Hold in the Navigation switch (4) while sliding the power switch to the On position. Keep the navigation switch held until a brief vibration pulse is emitted and the LED goes the colour **Red**.

4) Release the navigation switch immediately. The SK6 is now in firmware upgrade mode and waiting for a connection from the host. If the LED goes to the **orange** state, then go back to step 3

5) Ensure the SK6 is within a couple of feet of the host Bluetooth antenna

6) Unzip the files SK6_R*Abb*.hex and SK6_FU_*Cdd*.exe to any folder of your choosing on the PC

7) Double click on SK6_FU_*Cdd*.exe

8) Enter the COM port to which the SHAKE is connectable on (as obtained from step 8 of the getting started guide)

9) Once connected the LED (7) should go consistent **green** for the duration of the firmware upgrade. This can take up to 5 minutes to complete depending on the connection

10) If the upgrade was successful you should see “Target Verify OK” displayed in the console.

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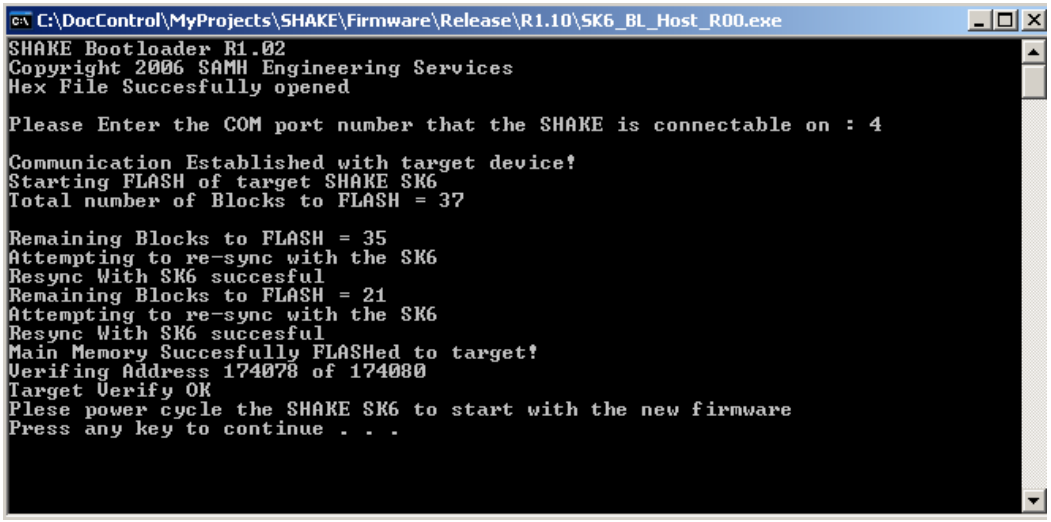
C:\DocControl\MyProjects\SHAKE\Firmware\Release\R1.10\SK6_BL_Host_R00.exe
SHAKE Bootloader R1.02
Copyright 2006 SAMH Engineering Services
Hex File Succesfully opened
Please Enter the COM port number that the SHAKE is connectable on : 4
Communication Established with target device!
Starting FLASH of target SHAKE SK6
Total number of Blocks to FLASH = 37
Remaining Blocks to FLASH = 35
Attempting to re-sync with the SK6
Resync With SK6 succesful
Remaining Blocks to FLASH = 21
Attempting to re-sync with the SK6
Resync With SK6 succesful
Main Memory Succesfully FLASHed to target!
Verifing Address 174078 of 174080
Target Verify OK
Plese power cycle the SHAKE SK6 to start with the new firmware
Press any key to continue . . .

Figure 21

11) Press return and the SHAKE will now be automatically instructed to run the new firmware and will enter standby mode

If the firmware upgrade fails for any reason, repeat the procedure from step 1

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SK6 Calibration Modes

All the sensors within the SK6 are calibrated at the factory however there may be circumstances where it is required to recalibrate certain sensors. It is recommended to run these calibration modes using a simple terminal application such as Hyperterminal for the MS Windows PC platform. This will ensure that the test output and instructions will display correctly. All of the calibration modes will write the results to non-volatile FLASH memory and are stored permanently or until such time as the calibration procedure is re-run.

Battery Full Level Calibration

This will calibrate the full level of the battery to the maximum battery indication output of 255 (0xFF). To perform this calibration, connect the SK6 to the charger and run the calibration mode by sending

```
$WRI,010A,05
```

Following the acknowledge packet, the following text will be output

```
Calibrating the Battery full voltage level
Make sure charger is connected. Waiting for the battery to be fully
charged
Waiting
```

Where the ‘Waiting’ text will flash periodically. Once the battery is fully charged, the calibration will be complete automatically (no user intervention is required).

Temperature Calibration

This is a simple single point calibration of the internal thermistor. The slope of the temperature curve is fixed and may lead to errors of up to 1degC per 20degC away from the calibration temperature. To start the calibration, send

```
$WRI,010A,04
```

to the SK6. Following the acknowledge packet, the following text will be output

```
Calibrating Temperature Sensor
Ensure thermocouple is inside closed SK6 case
Use NAV Up / Down to adjust the temperature, and press centre to
select
25 degC
```

Select the current temperature and press the navigation switch in the centre to complete the calibration.

External Analog Inputs Calibration

This simultaneously calibrates the DC gain of both external analog inputs. To start the calibration, send

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```
$WRI,010A,07
```

to the SK6. Following the acknowledge packet, the following text will be output

```
Calibrating the external analog inputs
Plug in the accurate 1.00V DC supply to the analog inputs and press
nav centre
```

Connect a well regulated low-noise source to both the analog inputs (see SK6 External Analog Inputs) and then press the navigation switch (4) in the centre position to complete the calibration.

Magnetometer Calibration

Calibrating the magnetometers is vital for proper operation of the compass heading algorithm. It may be necessary to re-calibrate if the SK6 is used next to an object that has some residual magnetism that interferes with the earth's magnetic field, for example if it is used when mounted to a PDA or mobile phone.

Note: It is important to perform this calibration while the charger is disconnected as the charging current will interfere with the magnetic field being measured. It is also advisable to perform the calibration in an open (preferably outdoor) location away from any magnetic materials such as steel or power cables.

The magnetometers can be calibrated to the earth's magnetic field if it is first known what the earth's magnetic field strength magnitude is at your current location. This can be found by visiting

http://www.geomag.bgs.ac.uk/gifs/wmm_calc.html

where the total field intensity is the parameter of interest. The units given on this webpage are in nT. The SK6 requires this value to be converted into mGauss units which can be done by dividing the nT value by 100. For example, if the total field intensity level at your location is 49,000nT, then the corresponding value in mGauss is 490mGauss. Once you have this value, you can proceed with the calibration by sending

```
$WRI,010A,01
```

to the SK6. After the acknowledge packet you will see -

```
Calibrating Magnetometers
Select the earth's magnetic field magnitude in mGauss at your present
location
Use NAV Up / Down to adjust the value, and press centre to select
500  mGauss
```

At this point enter the magnetic field value found above and press the navigation switch in the centre position. The SK6 will then output –

```
Calibrating Magnetometer +X axis. Orient SK6 towards earths magnetic
field vector to MAXIMISE the value displayed. Then press NAV centre
to calibrate
2100 Peak/Trough = 2104
```

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Orient the SK6 such that the current value reaches its peak or trough. It is helpful if you know the direction of the earth's magnetic field vector as this will reduce the time taken to home in on the peak / trough value. For example, referring to Figure 2 the +X direction is that in the direction from the centre of the SK6 away from the Aux connector with the unit upright. Thus the maximum can be quickly found by orienting the SK6 such this direction points in the same direction as earth's magnetic field vector, and slightly adjusting the orientation. The peak / trough values are held, and it is this value that is stored and used for calibration. The LED remains green during the calibration but goes briefly red if a new peak / trough are found freeing your constant visual attention from the terminal window.

This step must be repeated for each of –X,+Y,-Y,+Z and the –Z orientations. Once these steps are complete, the data in the magnetometer packets will be calibrated such that each unit will correspond to 1mGauss of magnetic field strength.

Note: If the navigation switch is awkward to press, then the sequence can be advanced by sending a semicolon ';' character instead.

Accelerometer Calibration

This is a simple two-point calibration of known acceleration levels, namely +1g and -1g. To enter this calibration mode, send –

```
$WRI,010A,02
```

to the SK6. After the acknowledge packet you will see –

```
Calibrating Accelerometer +X axis. Place SK6 top end on level surface
Keep the SK6 still - Calibration will commence in 5 seconds
```

Follow the instructions for the next 6 steps. It is advisable to have a spirit level to ensure that the surface on which you place the SK6 is level to earth's surface. If the SK6 is not kept still or is placed in the wrong orientation during this process, the SK6 will notify you to repeat the last step. Once this calibration is complete, the acceleration output data will be scaled to 1000 units per g (g is the acceleration due to gravity, ~= 9.81 ms-2). This procedure simultaneously calibrates both the +/- 2g and the +/- 6g accelerometer ranges.

Capacitive Sensors Calibration

This is a simple two-point calibration of the capacitive sensors, namely touched and not touched. The capacitive sensors are quite sensitive to variations in how the SK6 is held. For best operation, it is recommended that it is held such that the back face is flush to the palm of the user's hand, or to some other expose skin surface of the user. The capacitive sensor will also work if it is not held but connected to the charger, as this will create the current loop through ground (earth). This calibration should be performed for one of these scenarios (handheld or mains connected) only, and the calibration will be valid for that scenario only.

To enter this calibration mode, send –

```
$WRI,010A,06
```

to the SK6. After the acknowledge packet you will see –

```
Capacitive Sense Calibration Channel 0
Disconnect PSU,place SK6 face up on palm of hand and press
the navigation switch in the centre position
```

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Follow the instructions for the next three steps. Once this calibration has been completed, the data of the capacitive sensing packets will read 0 when the plates are not touched and 255 when they are touched. The value will vary between these values as the distance of the human body to the plates.

Angular Rate Sensors (Gyros) Calibration[16]

This is a simple two-point calibration of known rotation levels, namely +45 RPM and 0 RPM. 45 RPM was chose so that the calibration can be completed by using a vinyl record turntable. For accuracy it is recommended that a direct drive quartz locked turntable is used, such as the Technics™ 1200 series. It is also paramount that the turntable is on a level surface and that each stage of the calibration, the edges of the SK6 are parallel to the turntable platter. To enter this calibration mode, send –

```
$WRI,010A,03
```

to the SK6. After the acknowledge packet you will see –

```
Calibrating Gyro Pitch Axis rotating. Place SK6 left hand side on
rotating platter at 45 RPM
Calibration will commence in 5 seconds
```

Follow the instructions for the next 6 steps. Once this calibration is complete, the angular rate output data will be scaled to 10 units per degree per second.

[16] Angular Rate Sensor module (SK6-G01) must be installed for this to operate

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Document History

Revision #	Date	Changes
R00	12/09/2006	Initial Draft
R01	11/10/2006	Added Command Examples Removed CR and LF from command packets Added Section SK6 External Analog Inputs Added section SK6 Configuration Registers Added section SK6 Query Registers Added section SK6 Request Registers Added section SK6 Digital Filters Added section SK6 Vibrotactile Display
R02	17/10/2006	Added TOC
R03	20/10/2006	Modified temperature register address from 0x0107 to 0x0108 Added Navigation Switch activation packet details Added navigation switch entry to Module Power Control Register #1 Removed checksum field from data ,acknowledge and command packets Changed the format of the Capacitive Sensors Packet The “LED Flash Slow” period was changed from 2 to 3 seconds Added the section “SK6 Sensors” Added the section “SK6 Battery and Power Supply” added the section “The SK6 Data Packets in Raw mode” Updated section “Vibrotactile Display” Added “SK6 Calibration Modes” section
Rev A	29/11/2006	Calibration Request Register changed to 0x010A Fixed typo in vibration upload command example Fixed table of contents page references changed Digital Filter Control Registers table to indicate that the compass heading filter is not yet available Changed the default output data rate for the accelerometer from 25Hz to 5Hz Added Gyro calibration section
Rev B	01/12/2006	Modified Formatting Removed Compass Heading Filter Row from Table 8
Rev C	07/12/2006	Modified Raw data format to have an extra header byte value 0x7F, Table 5
Rev D	05/01/2007	Inserted Table 13 - Data Output Calibration Bypass Register Inserted Table 14 - Data Output Cross Axes Calibration Bypass Register Inserted Table 15 – Data Packet Streaming Disable Register Updated section SK6 Sensors section Overview to describe the streaming disable function Updated the calibration sections to calibrate the axes in the order x,y, z
Rev E	29/01/2007	Modified the display splash text in Run Mode paragraph Added Table 16 –Temperature Compensation Enable Register Added section SK6 External Vibration Driver Module, SK6-V01 Updated section Gyro / Angular Rate Sensor4F (option) to include a description of the temperature compensation
Rev F	16/03/2007	**Note: Functionality additions in this version apply to firmware versions 2.00 and later** Updated Table 11 - Digital Filter Control Registers with the compass averaging control byte Updated the paragraph Compass Heading Sensor Added the “Capacitive Sensors Threshold Packets“ paragraph in the section The SK6 Data Packets

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		Updated paragraph Capacitive Sensors Added Table 8 - Communications Configuration Register Added Table 17 - Capacitive Sensing Trigger Mode Control Registers Overhauled the section SK6 Operation Modes Updated Table 2 – LED Visual Feedback Added section - SK6 Data Logging Added data logging related register tables - Table 22, Table 26 ,Table 27 and Table 28 Overhauled the section SK6 Data Connections Updated Table 1 – Specifications of Sensors Added Table 19 - Data Request Register #2 – which includes the bit for accessing the firmware and hardware revision of the device Added text relating to sequence advancing by sending ';' in the Magnetometer Calibration section Updated The SK6 Data Packets in Raw (Binary) mode section with the capacitive sense trigger packet headers
Rev G	29/01/2008	Updated the paragraph Data Logging Status: to include the end of playback termination message Updated the SK6 Vibrotactile Display section to reflect that a zero time value cause playback to terminate. Added section H01 (Polar Heart Rate Monitor Receiver)
Rev H	22/04/2008	Added configuration bit in Table 10 - Data Output Format Register for enabling packet counter in raw data mode Updated section The SK6 Data Packets in Raw (Binary) mode to include the packet counter bytes Added configuration bit in Table 10 - Data Output Format Register for enabling packet time stamps in raw data mode and in the ACK and NAK packets Updated section The SK6 Acknowledge / Response Packets to include the option of having a time stamp appended. Added UART connection details to section SK6 External Analog Inputs Added Bluetooth security option, see section Bluetooth Security: and Table 8 - Communications Configuration Register
Rev I	13/12/2008	Updated SK6 External Vibration Driver Module, SK6-V01 section with details on driving external linear actuators Updated table - Vibration Request Registers with registers for driving external linear actuators.
Rev J	16/04/2009	Updated Table 10 - Data Output Format Register Added paragraph Pulsed drive and vibration profiles Updated section SK6 LED Visual Feedback with details on overriding the LED colour. Added Table 29 - LED colour override registers Updated section The SK6 Data Packets in Raw (Binary) mode to include raw packets with 'vibration motor applied voltage' field Updated Table 10 - Data Output Format Register Added more example raw data packets to section The SK6 Data Packets in Raw (Binary) mode